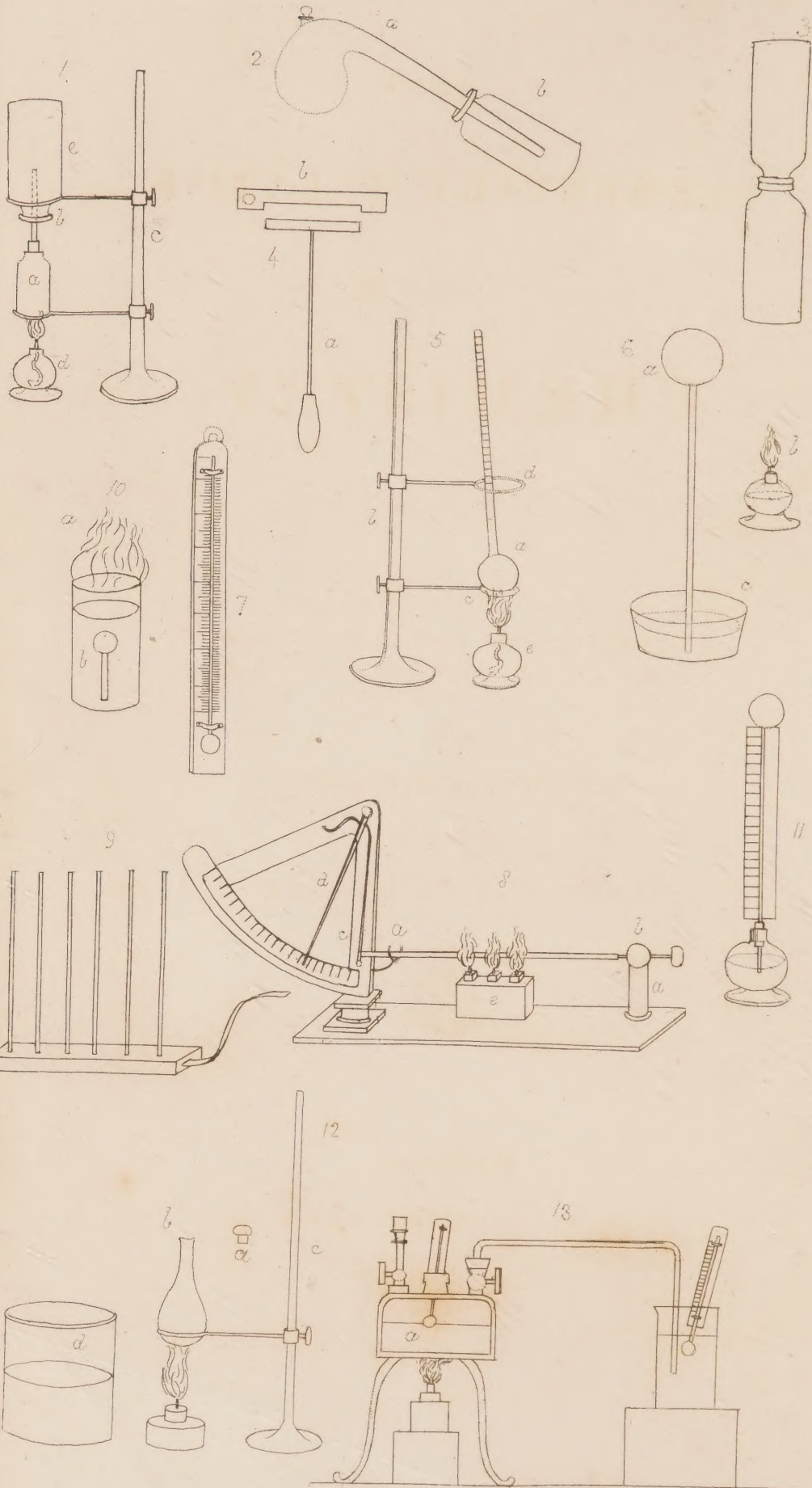


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AN
ELEMENTARY TREATISE
ON
CHEMISTRY:

INCLUDING

THE HISTORY OF THE SCIENCE; THE OPERATION OF POWERFUL
CHEMICAL AGENCIES; EXPLANATIONS OF THE NATURE
AND PROPERTIES OF THE MOST IMPORTANT INORGANIC
SUBSTANCES, AND THEIR USES IN THE ARTS;

WITH

NUMEROUS EXPERIMENTS

AND

ILLUSTRATIVE FIGURES.

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PREFACE.

THE intention of the following pages is to give a clear, concise, and plain account of Chemistry in its present state. The frequent enquiries made of the Author for such a book has induced him to prepare it for publication; he has anxiously endeavoured to introduce every thing necessary to a general and comprehensive view of the subject, and to exclude every thing calculated to confuse the minds of youthful enquirers, or to waste the time of those whose object is the acquirement of correct but general knowledge. The publication, it is hoped, will prove a useful and agreeable auxiliary in the instruction of youth; and a faithful remembrancer to those whose memories may require aid, but who may have neither opportunity nor inclination to explore the pages of more extensive works.

PREFACE.

The whole of the experiments introduced have been frequently performed by the Author, and nearly all the articles of apparatus figured and described have been in use by him.

It may be proper to remark that an essay, by the Author of this work, which was published a few years since in an Encyclopedia, has been taken for the basis of this publication: it has been corrected and enlarged, and rendered conformable to the present state of chemical science.

AN
ELEMENTARY TREATISE
ON
CHEMISTRY.

*Historical Sketch of the Origin and Early
Progress of Chemistry.*

The science of chemistry originated in the labours of the alchemists, who tried innumerable experiments, upon various kinds of matter, in search of the philosopher's stone; which they expected, when found, would enable them to cure all diseases, to prolong human life to a great extent, and to remove all poverty and want, by transmuting the baser metals into gold. Some persons pretended that they had succeeded in this discovery, and professed themselves capable of converting mercury and lead into silver and gold, by throwing upon them, while heated, a powder, which they called the powder of projection. They affected great mystery in their proceedings, and treated with contempt all who were not initiated into the practice of their art. Some of these alchemists appear to have been deceived themselves, and others were impudent impostors, whose sole aim was to practice upon the credulity of the public. It is impossible now to de-

termine the time, at which the idea of the practicability of transmutation began to prevail; the alchemists claim high antiquity for their art, but this claim is not very well supported by historical documents: they quote an edict of Diocletian, issued in consequence of a rebellion in Egypt, in which "their ancient books" which treated of the admirable art of making gold and silver, are commanded to be sought out, and committed to the flames." The historian Gibbon accounts this the first authentic record in the history of alchemy; but the authenticity of the edict itself, is not well established. A desire for chemical investigations, seems to have prevailed as early as the fifth century; and about the end of the seventh, or beginning of the eighth century, Geber, the Arabian, pursued the study of alchemy, and may be called the first systematic author in that art. Three books of alchemy, with the name of this author, containing accounts of the processes and theories of his time, with descriptions of a great variety of chemical apparatus, were published at Strasburg, in the year 1520. In this work, students of alchemy are required to prepare their minds for the performance of experiments, by persevering in charitable and pious acts; they are then permitted to hope, that they may be enabled "to change argent vive into an infinite solific and lunific, without the help of any thing more than its multiplication."

It is not surprising that the delusion of alchemy should have taken such firm hold upon the minds of men, when it is considered that those who possessed the greatest knowledge of the time were its disciples, and that it presented to their heated imaginations, prospects of prolonged life and unbounded wealth. It has been thought probable that the desire to search for the elixir of life, and the philosopher's stone, was first imbibed by our countrymen during the crusades. From the multitude of those who prosecuted these studies in different ages, the names of a few may be selected. Avicenna first divided substances into salts, earths, inflammables and metals. Arnald, of Villa Nova, and Raymond Lully, of Majorca, are celebrated by alchemical writers, as having actually possessed the art of transmutation; the former is said to have converted iron into gold, at Rome; and the latter, it is affirmed performed a similar operation in the presence of Edward I., in London; and it is farther pretended that nobles were coined of the gold made in this experiment. The injury done to society by the increasing infatuation of alchemy, at length required the interference of power to stop its progress; a bull was issued from the throne of Rome, in 1316, stigmatizing alchemists as impostors, because they promised what they did not perform: and in the fifth year of the reign of Henry IV., the following

act of parliament was passed, 5 H. IV *Statutes at large*, vol. i. p. 457. "None from henceforth shall use to multiply gold or silver, or use the craft of multiplication, and if any the same do, he shall incur the pain of felony."

So thick was the mental darkness of this period, that the great talents of ROGER BACON were not able to illuminate the gloom; his attempts to diffuse real knowledge, occasioned him to be suspected of witchcraft, and he had very nearly fallen a sacrifice to the ignorance and cruelty of the age. The *Opus Majus*, of this author, remains a surprising monument of the superiority which he had acquired over his contemporaries. There is an evident and striking resemblance between many of the opinions, and even some of the expressions, contained in the *Opus Majus*, and the opinions and expressions long afterwards published in the *Novum Organum* of lord chancellor Bacon. The invention of gunpowder is usually ascribed to friar Bacon, although other claims to this invention have been advanced with considerable plausibility. Albert, of Cologne, a contemporary of Roger Bacon, was distinguished by his invention of the brazen head, on account of which he was suspected of holding intercourse with the powers of darkness.

Basil Valentine, of Erfurth, made many important discoveries about the middle of the fifteenth century; notwithstanding, he was af-

fect, in a considerable degree, with the alchemical madness of the age. In addition to several important preparations of antimony, and other medicines, which he introduced, he first described the preparation of muriatic, sulphuric, and nitric acids; and he was one of the first who produced ether from sulphuric acid and alcohol. Paracelsus, of Basle, was the first lecturer on chemistry in Europe; and he made some important improvements in the healing art: he was so vain of his skillfulness in this art, that he imagined himself capable of conferring immortality; but, alas! he died at Saltsburgh, in the forty-ninth year of his age. A. D. 1541.

In the year 1588, Van Helmont, of Brussels, was born; who, although educated in the school of alchemy, broke through its trammels, and distinguished himself by some correct and philosophical views. He first discovered elastic fluids, different from the air of the atmosphere, and called them gases. This philosopher distinguished also between permanently elastic and condensable gases; and he described and figured an instrument very like the differential thermometer.

The seventeenth century was marked by considerable progress in chemistry as a science. The absurdities of alchemy began gradually to be perceived, and were evidently on the decline, while rational and truly scientific theories began

to be entertained; and the instruments of research invented by the alchemists, were converted to the purposes of experiment, altogether unconnected with mystery and fraud.

About this period, Kunckel was deservedly held in high repute as a successful improver of the arts by the application of chemistry. This philosopher was in favour at different courts of Europe, but particularly at that of Sweden, where he was ennobled by Charles XI., in 1693.

Many important discoveries were made, and new processes invented, by Glauber of Amsterdam; his process for preparing muriatic acid, by distilling common salt with sulphuric acid, is very much the same as that now in use; and the sulphate of soda, which is a residue of this process, is still called Glauber's salt. The method of extracting vinegar from wood, now so extensively used, is another of the important discoveries of this philosopher; he was also a great inventor and improver of philosophical apparatus, and probably contributed more to the advancement of chemistry than any of his contemporaries.

The important system for the improvement of natural knowledge, promulgated by Lord Bacon, produced the happiest effect on the progress of chemistry, as upon other departments of knowledge. Until his time, men suffered themselves to be misled by imagination; they formed vi-

sionary hypotheses, and endeavoured to make nature and art bend to their fancies, instead of submitting themselves to these as their teachers and their guides. Lord Bacon taught that the most effectual means of acquiring useful knowledge, are observation and experiment: and he directed the attention of those who were anxious for improvement, to various instruments for assisting the senses in their important investigations. By this enlightened and truly philosophical system, men were instructed not to enter into speculations, but to be diligent in collecting facts; for they are the real materials of which useful knowledge is composed. This new mode of enquiry was at length adopted, and the progress of true science advanced with accelerated velocity.

At this period several learned societies were established in Italy, England, and France; by which talent was called forth and encouraged, and the diffusion of knowledge greatly extended. The Academy del Cimento, in 1651; the Royal Society of London, in 1660; and the Royal Academy of Sciences, in Paris, in 1666.

Boyle and Hooke were the first philosophers of eminence attached to the Royal Society; they were both very successful enquirers and experimentalists, upon the principles of Lord Bacon, to which they rigidly adhered. Some time before this, the increase of weight which metals acquired by calcination, had been explained by

Rey, a physician of Perigord, on the principle of the combination of air with metal. The air pump having been invented by Otto de Guericke, of Magdeburg, it was greatly improved by Boyle and Hooke, and successfully used by them in their enquiries into the properties of air; they were enabled to verify the assertions of Rey, and to throw more light upon this important subject. The conclusions at which they arrived ultimately in this investigation, were, that burning and breathing cannot be supported without a sufficient supply of air, and that one part of the air only is employed in these processes. Hooke also formed the idea that the part of the air which is necessary in these processes, is the same as that which is fixed in nitre; and he conjectured that a body on being burnt, combines with this matter. He explained also the burning of a candle, and thought that the light and heat arise from the action of the air upon the combustible matter of the flame; and to shew that the flame is a mere film, not luminous in the interior, he recommends looking down upon it, in order to view its sections, through a thin piece of mica or glass. Boyle first introduced the application of tests, in chemistry: among other uses of re-agents, he observed that acids redden vegetable blues, and that alkalies render them green.

The theory of combustion received farther illustrations in a work, called *Tracts on various Philosophical Subjects*, published by John

Mayow, in 1674. About the same time a new explanation of combustion was introduced in Germany by Beccher and Stahl, called the phlogistic hypothesis, which was generally received in preference to what had been advanced by Boyle, Hooke, and Mayow. The elementary bodies were considered by Stahl, to be water, acid, earth, and fire; and he called fire, phlogiston, considering it as a distinct principle which enters into combination with various bodies; and by the agency of which, the phenomena of combustion may be explained. A few examples of his mode of reasoning will explain his views. Because charcoal is entirely consumed in burning, he considered it to be nearly pure phlogiston. When metallic earths are heated with charcoal, they are converted into metals; phlogiston and metallic earths are therefore the ingredients of which they are composed. Zinc, when heated to redness burns with a bright flame, and leaves only a white earthly calx; zinc is therefore composed of this earth and phlogiston. Glauber's salt heated with charcoal, gives a compound of sulphur and alkali; he believed therefore, that sulphur is an acid combined with phlogiston. It will thus be seen that the effect of air on these processes, was entirely overlooked, although Rey had shewn the fixation of air in burnt bodies, and Boyle and Hooke, that bodies will not burn without air. This

hypothesis continued to prevail upwards of fifty years.

Sir Isaac Newton applied his powerful genius to explain and systematize the phenomena of chemical attraction. When carbonate of potash (says he) is exposed to the air, it deliquesces, which proves that an attraction exists between the salt and the moisture of the atmosphere. Common salt and saltpetre do not deliquesce, because such an attraction is wanting between them and moisture. Copper dissolved in aqua-fortis is thrown down by iron, because the particles of the iron have a stronger attraction for the particles of the acid, than those of the copper. Muriatic acid combines with salt of tartar by virtue of their respective attractions; but, oil of vitrol poured upon the compound, displaces the muriatic acid, by its own superior attraction.

The penetration of Newton, in anticipating future discoveries, was very remarkably shewn in the opinion which he expressed, that the diamond consisted of inflammable matter; and that water contained a combustibile element, because the refractive power which these possess, coincides with the refractive power of known combustibile substances. These conjectures, which have since been proved correct, were made long before the real nature of these substances was discovered.

The investigation of Dr. Hales in the early part of the eighteenth century, were carried on with great diligence and originality ; he made many important experiments and observations on air, and on growing plants ; he found that air formed constituent parts of many substances, and had he pursued his experiments with zeal and perseverance, he might have anticipated the discoveries of succeeding philosophers.

Boerhaave, of Leyden, pursued similar investigations ; he believed that the air owes its elasticity to its combination with fire ; and thought that its ponderable matter might be capable of entering into chemical combination.

For some time previous to the year 1756, the causticity of earths and alkalies had occasioned much controversy. Some persons attributed the conversion of limestone into quicklime, to certain igneous particles imbibed by the lime from the fire. Others thought that the particles which occasioned the change were acid, and others believed them to be saline. In the year alluded to, Dr. Black published his researches on calcareous, magnesian, and alkaline substances, by which he proved the existence of a gas different from common air ; he gave it the name of fixed air ; and demonstrated that limestone and alkalies become caustic by being deprived of their fixed air.

The discovery of one elastic fluid, differing

from common air, induced philosophers to search for others, and this new branch of enquiry led to very important results. Soon after the commencement of these researches, the apparatus for examining gases, confined by water, was introduced by Mr. Cavendish; with this apparatus he made a great number of interesting experiments on different kinds of air; particularly hydrogen, the properties of which he first examined and described.

About 1768, Dr. Priestley commenced his researches, by pursuing some of the experiments of Dr. Hales, and inventing many that were original; he greatly improved the apparatus for the examination of gases over water; he invented the mercurial apparatus for investigations on gases which being made to pass into water, were absorbed by that fluid; he contrived a method of weighing gases, and of applying the influence of electricity to them. The researches of this philosopher were carried on with unwearied industry, and were crowned with an extraordinary degree of success.

He investigated the nature of nitrous gas, which had been previously noticed by Mayow; he discovered nitrous oxide, muriatic acid gas, sulphurous acid gas, ammonia, and oxygen, which was then called dephlogisticated air. He also investigated the action of plants upon air, and demonstrated their beneficial agency in purifying the atmosphere.

At the same time chemistry was making rapid progress on the continent of Europe, prompted by the labours of Macquer, Rouelle, Margraff, Pott, and others. The great talents of Bergman, of Sweden, were happily applied to elucidate chemical attraction, and to the generalization of the newly discovered phenomena of science. Scheele, another eminent Swedish philosopher, discovered several of the gases, without knowing what Priestley had done; he examined successfully the composition of the atmosphere; he discovered the fluoric and prussic acids, and chlorine, which was then called dephlogisticated muriatic acid; he very much enlarged the knowledge of heat, and distinctly described its radiation. The circumstances of this philosopher's life afforded remarkable encouragement to the lovers of science, who, destitute of fortune and friends, are ready to sink into despair on viewing the apparently insurmountable obstacles, which seem to be opposed to the successful pursuits of their favourite studies. The distinguished individual alluded to, was of humble birth, placed in a remote and obscure situation, with irksome and imperative duties to perform; yet, notwithstanding, by the united influence of industry, fortitude, and genius, he rose into distinction as one of the first philosophers of the age.

The phlogistic hypothesis of Stahl still maintained its ground in opposition to the rapid

advancement which had been recently made, and which was now making in chemistry. It was in vain to enquire into the nature of phlogiston; it was an imaginary principle, assumed to help in explaining the phenomena of combustion; while its introduction tended only to involve the subject in greater obscurity. The influence of this famous hypothesis, was now however on the decline; the remarkable properties of hydrogen, induced some of the most eminent philosophers of this period, to assume that gas as the inflammable principle. But Lavoisier was destined to be the principal agent in accomplishing the downfall of phlogiston. The doctrine which he maintained is, that oxygen is a compound of a base with the matter of heat, and that, in the act of burning, this base unites with the combustible body, and the heat is set free: he maintained that it is quite unnecessary to suppose the existence of phlogiston, or of any distinct principle of inflammability, in order to explain the phenomena of combustion. Lavoisier ranked high among scientific men, on account of his clearness of judgement, the depth of his penetration, and the elegance and correctness of his illustrations.

An important plan for improving chemical nomenclature, was brought forward in 1787, by the French chemists, Lavoisier, Morveau, Berthollet, and Fourcroy, which was founded upon

the excellent idea of calling simple substances by names, which would indicate their most characteristic properties, and of deriving the names of compounds from the elementary parts of which they are composed. The adoption of this new nomenclature, which soon became general, added to the precision of chemical science, and greatly assisted in diffusing the important truths of which it is composed. From this period the advancement of chemistry has been rapid and progressive; its important principles now form essential parts of various improved arts and manufactures; and it contributes in no small degree, to the elegance and comfort of human life. From being the plaything of the idle, the pursuit of the insane, or the instrument of the designing—it has become the promoter of civilization, the supporter of states, the nerves of the arts of peace, and the sinews of the art of war.

CHEMISTRY.

THE OBJECT OF CHEMISTRY IS TO INVESTIGATE THE NATURE OF ALL SUBSTANCES, WHETHER THEY ARE SIMPLE OR COMPOUND, WHAT PROPERTIES THEY POSSESS, AND WHAT EFFECTS THEY ARE CAPABLE OF PRODUCING UPON EACH OTHER, UNDER ALL POSSIBLE CIRCUMSTANCES.

This definition seems to point out the propriety of first enumerating the simple substances that (according to the present state of knowledge) are the elements from which all others are compounded; then to describe the agencies by which

changes are effected upon these substances; and lastly, to describe these substances, relate the individual changes which they have been made to undergo, and consequently the combinations into which they enter. It will be necessary also to describe the most useful instruments used in effecting these important chemical changes.

The simple substances are fifty-three in number; and are divided, from a consideration of their properties, into several classes; the first class comprehends five substances.

Oxygen	Iodine	Fluorine
Chlorine	Bromine	

The second class—

Hydrogen	Sulphur	Carbon
Nitrogen	Phosphorus	Boron

The third class is composed of metallic substances—

Gold	Manganese	Sodium
Silver	Tungsten	Lithium
Copper	Tellurium	Barium
Iron	Molybdenum	Calcium
Mercury	Uranium	Strontium
Tin	Titanium	Magnesium
Lead	Chromium	Silicium
Zinc	Columbium	Alumium
Bismuth	Palladium	Yttrium
Antimony	Rhodium	Glucinum
Arsenic	Iridium	Zirconium
Cobalt	Osmium	Thorinum
Platinum	Cerium	Selenium
Nickel	Potassium	Cadmium

The most active agencies in effecting chemical changes, are

Attraction

Heat

Light

Electricity

ATTRACTION.

It is the influence of the attractive force, capable of being exerted by the particles of matter upon particles of other kinds of matter, to which we are indebted (under Providence) for the beautiful and useful variety that exists in the universe. The infinitely varied colours of vegetation, the refreshing green of the meadow, and the brilliant hues of the parterre, are derived from light, attracted and decomposed by growing plants. The salubrity of the atmosphere is promoted by the power which plants possess of attracting and decomposing carbonic acid gas, which is a product of burning and breathing; and solid substances derive their almost infinite variety of appearances and properties from the exertion of chemical attraction. To illustrate this, let any Tyro, who is anxious to understand these important agencies, consider the combination of oxygen and lead. When lead is melted in an iron ladle, its surface is bright at the moment of melting, but soon becomes obscured by the collection of a dull looking matter, which we commonly call dross, upon its surface; this change of appearance is occasioned by the combination of

the oxygen of the air with the lead. The lead being heated acquires the power of decomposing air, by attracting and combining with its oxygen; and if it is kept hot sufficiently long, the whole of the lead will unite with oxygen, and assume the state of oxide of lead: and as lead is capable of combining with different proportions of oxygen, it assumes different colours and appearances; first it is grey, then yellow, and afterwards, if long enough exposed to heat, under favourable circumstances, it becomes of a beautiful red colour: these changes being produced by the combinations of lead with different proportions of oxygen. In similar ways thousands of other changes are accomplished by the influence of chemical attraction. We avail ourselves of this influence in preparing our food and our beverage; a very large proportion of our articles of clothing must be submitted to the same influence, before they are ready for use; and the air that we breathe cannot assist in promoting vitality until it is modified by this all-powerful agency.

Dyeing is a process which is effected chiefly by the agency of chemical attraction. The particles of cloth, or other substances to be dyed, which readily receive colour, have an attraction for the colouring particles. In many cases, however, this attractive force does not exist between the substance to be dyed, and the dyeing material. Supposing the substance alluded to, to be a piece

of cloth; under these circumstances, if dipped into a solution of the colouring matter, it will only be stained in parts, not effectually dyed. In such cases, the dyer has been taught by chemistry to use some substance having an attraction both for the article to be dyed and for the colouring principle; such substances are called mordants. The articles to be dyed being first immersed in a solution of one of these, they are dried, and afterwards immersed in the dyeing vat, they then receive and retain the colour. It is by the skilful management of the same agency, that success is obtained in a very large proportion of the processes in the arts and manufactures. It will be sufficient, at present, to adduce one more example of its application to one of the fine arts. An engraver, about to engrave a landscape on copper, takes a clean and highly polished plate of that metal, and, having heated it, he covers its surface with a prepared coating of wax; when this coating of wax is cold, it is blackened by holding it over the flame of several wax tapers joined together. The plate is then prepared for the next process, which is called etching, and consists in drawing the design to be engraved by removing the wax with steel points, tracing all the lines through the wax upon the surface of the copper; this part of the process being finished, a border of soft wax is put round the plate, and diluted nitrous acid is then poured on, which,

having an attraction for the copper, attacks and dissolves a portion of it, wherever it has been exposed by the removal of the wax ground. When the lines requiring least depth are sufficiently corroded, the acid is poured off the plate, which is dried; and these lines being closed up with varnish, the liquid is again poured upon the plate, to deepen other lines, which are in their turn stopped; the process being continued until the acid has produced the desired effect on those lines which require to be deepest. The work is completed by the sharp point of the graver. It will appear from this description how much the engraver is indebted to the agency of chemical attraction for facilitating his process, enabling him to produce greater effect with less labour than could be produced in any other way. The process just alluded to is technically called *biting-in*.

Most of the experiments to be introduced throughout this work will be illustrative of chemical attraction; it will only be necessary, therefore, to introduce in this place a few very simple experiments for that express purpose.

Ex. 1. Add a little magnesia to clear water in a wine-glass, which will produce a white mixture, the water being incapable of dissolving the magnesia; the addition of a little sulphuric acid will again render the liquid clear, because the acid and the magnesia, having a strong attraction

for each other, combine to form sulphate of magnesia, which remains in solution, and which may be obtained in a solid state by evaporation and crystallization, or by evaporation to dryness. The carbonic acid previously combined with the magnesia being expelled in the state of gas, which occasions a rapid effervescence while the acid is acting upon the magnesia.

Ex. 2. A saturated solution of muriate of lime may be obtained by dissolving white marble, or any other variety of carbonate of lime, in muriatic acid, until a portion remains undissolved. To about two tea spoonfuls of this clear solution in a wine glass, narrow at the bottom, add about an equal quantity of a clear saturated solution of sulphate of magnesia, and agitate them, an almost solid substance will result. The sulphuric acid of the sulphate of magnesia having a much stronger attraction for lime than lime has for muriatic acid, the sulphuric acid and the lime combine together, and produce an almost solid white compound of the sulphate of lime. The muriatic acid and the magnesia having also combined at the same time.

Ex. 3. Into one wine glassful of water, drop about a tea spoonful of strong solution of sulphate of soda (Glauber's salt); and into another wine glass, nearly full of water, put the same quantity of strong solution of sulphate of magnesia; then place

beside them, a bottle containing some clear solution of muriate of barytes. If you add a little of the latter to each of the two former, a new arrangement of the constituent parts will take place; for, since barytes has a stronger attraction for sulphuric acid than that acid can exert for soda, when muriate of barytes is poured into the solution of sulphate of soda, the sulphuric acid of that compound and the barytes of the muriate of barytes attract each other, forming an insoluble white precipitate of sulphate of barytes; while the muriatic acid of the muriate of barytes, and the soda of the sulphate of soda, being set free from their former combinations, attract each other, and unite, constituting muriate of soda, which remains in solution.

When muriate of barytes is added to the sulphate of magnesia, contained in the second glass, the compounds are both decomposed, and two new compounds are produced, sulphate of barytes and muriate of magnesia; the latter remaining in solution, and the former being thrown down as a white opaque precipitate.

The whole of the processes belonging to the following experiment will clearly exemplify the force of chemical attraction.

Ex. 4. Equal proportions of lime, which has been slacked by exposure to the atmosphere, and muriate of ammonia, both in fine powder, being

put into a small earthenware bottle, *a*, fig. 1, furnished with a glass tube, *b*, securely fitted into the neck of a bottle, by passing through a cork; the bottle is placed upon the rings of the brass stand, *c*, heat being applied by the spirit lamp, *d*. In a short time after the application of the heat, the muriate of ammonia will begin to be decomposed, in consequence of the attraction exerted by the lime for muriatic acid; muriate of lime will be formed, and ammonia will be set free in the form of gas, which, being lighter than the air of the atmosphere, will readily ascend into the bottle, *e*, resting upon the ring over the tube; the gas ascends into the upper part of the bottle, and expels the heavier air at its mouth. Obtained in this way, the gas will be sufficiently pure for the experiment intended to be performed with it. When the bottle is full and the gas is escaping, the circumstance may be known by the pungent smell of the gas experienced near the bottle, or by holding the stopper of a bottle, or glass rod, moistened with muriatic acid, near the mouth of the bottle, *e*; should the gas be escaping it will combine with the acid, and produce dense white fumes in the atmosphere. This gas is corrosive, and incapable of being breathed. To procure another gas (muriatic acid gas) requisite for the experiment about to be performed, put into a glass retort, *a*, fig. 2, about a table spoonful of common

salt, and pour over it a sufficient quantity of sulphuric acid to cover it: the attraction of the sulphuric acid for the soda of the muriate of soda will occasion the decomposition of that compound; sulphate of soda will be formed, and muriatic acid gas will be set free, which, being heavier than common air, a bottle may be filled with it by making the tube of the retort descend near the bottom of the bottle, as in fig. 2. Muriatic acid gas is also highly corrosive, and incapable of being breathed.

The bottles having been filled with the gases, and closed with their stoppers, they must be brought near to each other; the stoppers must be taken out, and the bottle containing the heaviest gas, the muriatic acid, must be inverted over the other, as represented in fig. 3. Bottles that have their rims ground, so as to fit each other, are the best adapted for this purpose. As soon as these transparent gases are thus brought near to each other, they unite, forming white opaque muriate of ammonia.

The great change usually produced upon bodies on which the force of chemical attraction has been exerted, is strikingly shewn by this experiment.

Chemical attraction is not exerted at sensible distances, like the attraction of gravitation, but only at distances too small to admit of being measured. On this account, the particles of bodies which are to be submitted to this kind of

attraction, must be brought near together; they must be pulverized, and the powders must be mingled; or the bodies must both be dissolved, and the solutions mixed; or they must be melted together by heat.

In many instances, when a third substance is added to a compound of two others existing in solution, that compound is decomposed, on account of a stronger attraction existing between one of its parts and the new substance added, than between those which were in combination before: as in ex. 1, where sulphuric acid is added to carbonate of magnesia; the magnesia quits the carbonic acid to combine with the sulphuric. By a figure of speech, this tendency of substances to combine with some bodies rather than others, is called *Elective Attraction*; which is said to be single when the constituent parts are separated from each other by the addition of a third; and double when two compounds being mingled they mutually decompose each other, two new compounds being formed.

So many circumstances interfere to modify the exertion of this kind of attraction, that it is often very difficult, and in some cases quite impracticable, to deduce by calculation the exact results of an intended process. The circumstances alluded to are cohesion, heat, specific gravity, insolubility, quantity, and others of less importance.

When Sir H. Davy had satisfactorily ascertained, by very numerous experiments, that chemical compounds may be decomposed by the agency of voltaic electricity, and that the same pole of a battery always attracts the same constituent part of a compound; he concluded that those substances which are attracted to the negative pole are positively electrified, and that those which are attracted to the positive pole are in a negative state of electricity; and, since substances differently electrified strongly attract each other, it was the opinion of that distinguished philosopher that the particles of bodies which unite together under the influence of what is called by the different names of chemical attraction, chemical affinity, or attraction of composition, are caused to unite by being in different states of electricity: in other words, it was the opinion of Sir H. Davy, that the cause of that force which makes particles of bodies different from each other combine together, when they are brought sufficiently near, and which is called chemical attraction, is no other than electricity, the particles of bodies so combining being in different states of electricity.

Definite Proportions and the Atomic Theory.

The investigations of Higgins, Richter, and others, gradually led to the establishment of the

theory of definite proportions in chemical combinations. It was observed by the latter, about the year 1792, that when two neutral salts are decomposed by double affinity, two new saline compounds, also neutral, are produced; from which he inferred that quantities of two alkaline bases, which are capable of neutralizing equal weights of any one acid, must be proportional to the quantities of the same bases requisite to neutralize the same weights of all other acids. Thus, 100 parts of sulphuric acid, or 68.20 parts of muriatic acid, neutralize 118.20 parts of potash; 100 parts of sulphuric acid also neutralize 71 parts of lime: it may be inferred, therefore, that 68 parts and a fractional quantity of muriatic acid will also neutralize 71 parts of lime. A series of tables were constructed by Richter, in which these relations of bodies were expressed in a numerical form. Dr. Wollaston constructed a table of this kind, founded upon the most correct analyses, and called it a table of *chemical equivalents*. This table he applied to a sliding scale, which is capable of affording extensive chemical information.

The important investigations of Mr. Dalton, together with the labours of other eminent chemists, have now incontrovertibly established the fact, that, when bodies combine in more than one proportion, the additional proportions are exact multiples of the first. Thus, 6 parts of carbon

combine with 8 parts of oxygen to form carbonic oxide gas; carbonic acid being constituted of 6 parts of carbon and 16 parts of oxygen, such being the exact proportions by weight obtained in those compounds by analysis.

Mr. Dalton, in order to account for the uniformity of the proportions in chemical compounds, advanced the atomic theory, which had been previously alluded to, without his knowledge, by Mr. Higgins. According to this theory, which has been ably expanded, illustrated, and applied by Mr. Dalton, bodies that combine by the force of chemical attraction, unite together by their smallest parts or atoms, so that the most minute portion of the compound capable of being submitted to analysis affords portions of both the constituent parts. When bodies unite in one proportion only, the compound is believed to be formed by one atom of the one body with one atom of the other; this is called a *binary* combination. When one atom of one body combines with two of another, the combination is called *ternary*; one with three constitutes a *quaternary* combination.

The relative weights of the component parts of substances which combine together are discovered by careful analysis; and from these (believing that bodies unite by their atoms only) Mr. Dalton deduces the relative weights of the atoms themselves. Thus, if four parts, by weight, of one

body, A, unite with five parts, by weight, of a body, B, to form a binary compound, the relative weights of the atoms of these bodies, if it be admitted that they combine atom to atom, will be as four to five. The term *atomic weight* does not, therefore, mean the actual weight of the atoms, which cannot be ascertained, but merely their relative weights compared with each other.

In the statements of this theory, a variety of terms are used that mean the same thing; thus, atom, atomic number, equivalent, proportion, proportional, and combining proportion, are all occasionally used in the same sense; and they refer either to the smallest proportion in which a body is capable of combining with another, or to the aggregate amount of the compound atoms, resulting from the combination of the elementary parts.

The accuracy of the number representing the atomic weight of any elementary body, may be rendered apparent by deducing the same number from various compounds of the elementary body in question. Thus the weight of hydrogen in water is to the weight of oxygen in the same fluid as one to eight; in sulphuretted hydrogen gas, the weight of hydrogen is to that of sulphur as one to sixteen; and in carbonic oxide, the weight of oxygen is to that of carbon as eight so six. So that the estimation of the relative weight of an atom of hydrogen is the same whether it be de-

duced from its combination with oxygen in water, or from its combination with sulphur in sulphuretted hydrogen gas; and the relative weight of an atom of oxygen is the same whether it is obtained from its combination with hydrogen in water, or from its combination with carbon in carbonic oxide.

Since no combination of oxygen and hydrogen is known containing a smaller proportion of the latter compared with the former, it is believed that one atom of the one combines with one of the other; and, since the oxygen in water is eight times as heavy as the hydrogen in the same fluid, it is inferred that an atom of oxygen is eight times as heavy as an atom of hydrogen. Again, since oxygen and carbon are not known to combine together in smaller proportions than those discovered by analysis in the composition of carbonic oxide, it is believed that they unite by one atom of the one to one atom of the other; and, since the proportions, by weight, obtained by analyzing this compound are eight parts of oxygen to six parts of carbon, it is believed that the atoms bear the same proportion, by weight, to each other. The proportional weights of the atoms of other bodies may be found by similar means.

Numerical expressions of the relative weights of the atoms of bodies, and, consequently, of the definite proportions in which bodies combine

together, afford assistance and facility in calculating probable results, and in stating and remembering the actual results of chemical operations.

Considerable advantages have also been derived from the theory of volumes in the combination of gases, introduced by M. Gay Lussac. According to this theory (and it agrees with actual experience) gaseous bodies combine one volume of one to one volume of another, or one volume of one to several volumes of another, all the volumes being equal. In many instances, this theory agrees so nearly with the atomic theory, that volume being substituted for atom the conclusion is the same.

HEAT.

It is highly interesting and instructive to observe the admirable provisions which exist in the universe for restraining and limiting the operations of powerful agencies.

Considering attraction at large, its tendency is to draw the particles of bodies closer and closer together, so that fluids submitted to its unrestrained influence, would be converted into solids, and solids themselves would become harder and heavier, and denser, than they now are. If attraction were to prevail unrestrained, the earth and the seas would be bound

up in impenetrable ice, and cease to be the animated abodes of animal and vegetable life; but this equally powerful agent, heat, has been commissioned to penetrate every pore of matter, and counteract the deadly influence. On the other hand, if the power of heat were to preponderate, the particles of bodies would be separated from one another, and dissipated in space. There is, however, an accurate balance of force established between them, which, as long as it is the will of Providence to maintain, will secure to the rolling waters their freedom of motion, and to the inhabitants of the green earth the countless blessings of fertility.

The nature of heat, or, as it is most usually called in chemistry, caloric, is unknown. Many philosophers have believed that heat is a material substance; the particles of which being introduced among the particles of other bodies, occasion them to become hot. Another hypothesis is, that heat is not material, but merely an effect produced among the particles of bodies by motion, whether vibratory or rotatory; those who maintain this opinion, suppose that there is some analogy between sound produced by the vibration of a musical string and heat resulting in different degrees, from different intensities of motion. The ingenuity displayed by the supporters of these opposite hypotheses, has failed to produce de-

monstration; the nature of heat, like that of other refined agencies, being still entirely unknown.

Lavoisier introduced the term *caloric* to distinguish the cause of heat from the sensation which receives the same name.

The effects produced by heat have been carefully investigated; and it is universally known that when heat is applied to bodies they expand, the enlargement of bulk being in many cases very considerable, and productive of very important consequences. Such effects, as produced upon solids, fluids, and æriform bodies, may easily be illustrated.

Ex. 5. A solid piece of brass, *a*, fig. 4, being fitted to a notch in a flat piece, *b*, so that it may just pass through lengthwise and endwise, when cold; let it be heated in the fire until it begins to appear red in the dark, it will then be too long to pass through the notch, and too thick to pass through the round hole. Being allowed to cool it will pass through as before it was heated.

Ex. 6. To demonstrate the expansion of a fluid by the application of heat, let a glass bulb, *a*, fig. 5, having a long tube, filled with water, coloured with a little tincture of litmus, or sulphate of indigo, and placed upon the rings of the brass stand, *b*, so that the bulb may rest upon the small ring, *c*, and the tube against the larger ring, *d*. The upper half of the tube should be divided into a number of equal parts, by marks

upon the surface, made with a file or a diamond. The liquid in the tube should stand exactly at the first mark, and the ring which supports the tube should be placed just there, so that the surface of the liquid in the tube, the upper surface of the ring, and the first mark on the tube may all coincide. The heat of a spirit lamp, *e*, being then applied, the coloured liquid will very soon begin to ascend. The heat of a spirit lamp will continue very nearly equal as long as it is well supplied with spirit of wine. Let the heat of the lamp be applied for five minutes, and observe how many of the equal divisions on the tube the liquid passes by in its ascent; continue the heat during five minutes more, and the liquid will be seen to pass by a greater number of divisions in the second five minutes than in the first; from which it will appear that fluids do not expand equally with equal proportions of heat applied. Every successive portion of heat applied to a fluid produces a greater degree of expansion than the preceding portion, until the fluid arrives at the boiling point. The cause is thus explained; the particles of the fluid at any given temperature are held together by a certain force of cohesive attraction; the first portion of heat having opposed to it the whole of this force produces a less degree of expansion than the second equal proportion of heat, because it has less of the attractive force, opposed to the expansion of the liquid, to

contend with, a portion of that force having been overcome by the first quantity of heat applied. Thus every successive proportion of heat applied produces a greater effect, having less resistance to overcome.

The expansion of the fluid by the application of heat is rendered very evident by this experiment, notwithstanding the enlargement of the containing vessel by the application of the same heat.

Ex. 7. To demonstrate the expansion of air, take another glass bulb, *a*, fig. 6, similar to the one used in the last experiment, but perfectly dry within; hold the bulb over the flame of the spirit lamp, *b*, until it is very hot: the air within will be heated, and very much expanded; consequently, a considerable portion of it will be expelled from the tube. Remove the bulb from the lamp, and plunge the open end of the tube in water, contained in the vessel *c*; as soon as the heated air comes in contact with the water it will be cooled, and will contract into its original bulk, which contraction, destroying the equilibrium of pressure between the inside of the bulb and the outside, the pressure of the atmosphere will force water to ascend into the bulb, until it fills the space occupied by the air expelled: the equilibrium of pressure will then again be restored. The degree of expansion undergone by the air is thus rendered evident, for the exact space previously

occupied by the air expelled, will now be occupied by water: and, when the bulb was in a heated state, the air which now remains in it was expanded so as to fill the whole of the bulb and tube. The arrangement of apparatus for this experiment is shewn at fig. 6.

The utility of this expansive power of heat, combined with the contraction of bodies that ensues on withdrawing heat, may be illustrated by referring to a simple and common process. After the wooden parts of a carriage wheel are fitted together, they are to be secured by the iron rim which is afterwards put on. The inner circumference of this strong circle of iron is, on purpose, made smaller than the outer circumference of the wooden wheel, so that it will not go on until it is heated; by being heated the circle is enlarged sufficiently to enable the wheelwright to put it on, but the wood would be injured by the heat of the iron, if the latter were not suddenly cooled by throwing cold water upon it. The iron, in cooling, contracts very considerably, binding the parts of the wheel together in a very effectual manner.

To illustrate the effects of the same principle of the expansion of bodies by heat, reference may be made to the agency of the air in preventing the earth from being excessively heated by the rays of the sun. Whenever the earth becomes hotter than the atmosphere, that portion of the

air nearest to the earth receives some of the heat, by which it is expanded, and rendered lighter, bulk for bulk, than the unheated air above it, and immediately ascends, permitting another unheated portion of air to approach the earth, upon which the same effects are produced; and this process is continued as long as there is much difference between the heat of the earth and the air. While other important effects in the economy of nature are produced by the heated air which ascends into the higher regions of the atmosphere, occasioning winds, or currents of air, to proceed in particular directions over the surface of the globe, tending to equalize its temperature.

In the processes of the arts, the power of some substances to attract others and combine with them, is favoured by heat; as when metals are heated, their power of combining with oxygen is greatly increased. In other processes, equally important effects are produced by the expansive power of heat assisting in the decomposition of bodies, by repelling the particles of compounds to greater distances from each other, and thus aiding the other agencies intended to effect the decomposition.

Some other effects capable of being produced by expansion and contraction, according to temperature, may be briefly mentioned, as they require to be guarded against. Vessels or plates of glass are liable to be broken by sudden increase or decrease of temperature on one side; as when

boiling water is poured into a vessel of thick glass, without the precaution of warming it a little previously. The glass cracks because, being a bad conductor of heat, the heat that is applied to one surface expands it considerably, without being able to get through to expand the other surface in the same degree. The inequality of expansion is the cause of injury. Boiling water may be safely poured into a very thin glass vessel, as a Florence flask, because the heat passes through in time to prevent too much inequality of expansion.

Plates of glass, such as electrical machine plates, are often broken by setting them near the fire to warm them. Being heated on one side by the fire, and probably cooled on the other by a current of cold air rushing to the fire, expanded by heat on one side, and contracted by cold on the other, the plate cracks at the centre. On this account it is always dangerous to set such machines before the fire.

Sudden changes of a similar kind are dangerous to other substances, plates of cast iron have very frequently been broken by throwing water upon them when very hot.

As metals expand when temperature increases, and contract when it diminishes, considerable care is required in mixing large masses of them with other materials in building, for the alternate expansion and contraction of such masses cannot tend to increase the stability of any structure.

Exceedingly injurious effects are produced upon watches and clocks of common construction by the expansion and contraction of balance wheels and pendulums, in consequence of variations of temperature, occasioning irregularities in their movements; and great ingenuity has been exercised to obviate such defects. The contrivance most commonly adopted for clocks is the *gridiron pendulum* of Harrison, which is a combination of three bars of steel, and two compounded of zinc and silver. These are arranged, and the weight is suspended in such a way that the expansion caused by heat in the steel is counteracted by the expansion of the other bars, so that the pendulum remains always of the same length.

A contrivance upon the same principle, and for the same purpose, applied to watches, was invented by Arnold, and is called the compensation balance, which is composed of interrupted concentric portions of different metals, so adapted that the expansion of the one counteracts that of the other.

The principle of expansion by heat, and contraction by cold, is elegantly illustrated by the action of the thermometer, fig. 7. This instrument, composed of a glass bulb and tube, properly supplied with some liquid, which is usually quicksilver, and for some purposes coloured spirit of wine, the smallest increase of heat producing a corresponding expansion in the liquid, it rises

higher in the tube, and the degree of increase is judged of by the height to which the liquid rises in the tube along the graduated scale applied to the instrument. The smallest quantity of heat withdrawn occasions the liquid to contract and sink down in the tube, and the reduction of temperature is estimated by the depth to which the liquid subsides.

By the term *Law of Nature* is meant a certain order established at the Creation, and maintained by Providence. In this sense it is a law of nature that bodies should expand when they receive heat, and contract when they lose it. There are a few exceptions to this law, such as the contraction of clay when exposed to great heat, which arises from the expulsion of water, and the expansion that water undergoes previously to its being cooled to the freezing point. The last mentioned phenomenon is a very remarkable one. When water contained in a thermometer tube is exposed to a cooling process, either natural or artificial, it continues contracting in bulk until it arrives at 40° according to Fahrenheit's scale, it then begins to expand, although the cooling process be continued, and continues expanding until it arrives at 48° upon the same scale; proving this curious fact, that when water arrives at 40° in the process of cooling, it then begins to ascend, whether the cooling process be continued, or heat be applied, the

same effect being produced in either case as high as 48° . The cause assigned is, that previously to the water assuming the solid form, its particles enter into a new arrangement, which arrangement, requiring more room, occasions the expansion alluded to. This expansion of water just before it freezes is productive of very beneficial effects; for, if the bulk of water were not increased before it becomes solid, ice would be heavier than water, and if ice were heavier than water it would sink to the bottom; other films of ice would be formed in succession by the influence of frost, which would also subside, so that in a short time the whole of the water would become solid: but since ice is lighter than water, for the reason stated, it remains on the surface, protecting the water below from the influence of frost.

When the relative expansibility of metals, or other substances, at low degrees of temperature is to be ascertained, an instrument called a pyrometer, similar to the one represented fig. 8, may be used. The rods of different substances that are to be compared with each other, being of the same length and thickness, are placed in succession upon the rests, *a a*, one end being against the screw that passes through the strong pillar, *b*; the place of the screw being adjusted so as to make the other end of the rod touch the part, *c*, of the movable index, *d*. The heat of the spirit lamp, *e*,

being applied, the rod will begin to expand in length and thickness; as the length increases, the part, *e*, is more and more pressed upon, occasioning the point, *d*, to move along the graduated scale, which is divided into 100 equal parts. Care must be taken to apply the heat of the lamp the same length of time to each rod.

Conducting Power of Bodies.

Heat passes with different degrees of velocity through different substances. Metallic bodies are the best conductors of heat; but there appears to be no invariable relation between the density of a metal and its conducting power, as the heaviest of all the metals, platinum, is one of the worst metallic conductors.

Ex. 8. Hold between a finger and thumb slender pieces of different substances, several inches in length, say silver, glass, and charcoal, let the other ends of them be over the flame of a spirit lamp. The silver will become too hot to hold before the glass will be felt very warm, and the charcoal, while it burns at one end, will not produce the least sensation of heat at the other.

Ex. 9. A number of rods of different metals and other substances, about nine inches in length and a quarter of an inch in thickness, being loosely fitted to holes in another piece of metal, fig. 9, coat about four inches of each rod with bees'-wax, and place all the rods in their stand.

The stand may then be placed upon a heated piece of iron, or it may be plunged into some boiling water. The relative conducting powers of the different substances may be judged of by the different lengths of time required to melt the wax on the different rods.

Ex. 10. To shew the great difference between the conducting power of metal and wood, a piece of clean writing paper may be closely wrapped round a cylindrical piece of metal, about eight or nine inches in length, and from one to two inches in diameter. The paper so circumstanced may be held for several minutes in the flame of a spirit lamp without being scorched; but if a similar piece of paper be wrapped round a cylinder of wood of the same size as the metallic one, and held in the flame, it will very soon be scorched. The difference of effect is thus explained: when the paper is closely wrapped round the metal, the heat that is applied to one particular part cannot accumulate there, because the metal, being a good conductor of heat, receives that which is applied to the paper; the heat being diffused throughout the whole substance of the metal, and the paper cannot be scorched until the whole of the metal becomes very hot. When paper is wrapped round a piece of wood it is soon scorched, because the wood, being a bad conductor of heat, does not readily receive the heat that is applied to the paper, which, therefore,

quickly accumulates in sufficient quantity to produce the observed effect.

An uninstructed person on touching iron and wood in the same apartment in cold weather, would suppose the iron to be colder than the wood, because of the greater sensation of coldness produced by touching the iron; but the supposition would be erroneous, for iron and wood, under these circumstances, would be at the same temperature: the cause of the apparent difference is the different conducting power of these substances. When the hand touches the iron, heat rapidly quits the hand to enter into it, as there is a strong tendency to an equilibrium or equality in heat; whenever one body has much more than another, a portion will leave that which has most and enter into that which has less. Wood not being so good a conductor as iron, when it is touched by the hand heat is not so quickly withdrawn from the latter, and, consequently, the sensation of cold produced is proportionally weaker.

Earthy substances, although better conductors of heat than wood, are very inferior to metals in that respect; so slowly does sand conduct heat, that the red hot balls used at Gibraltar, in repelling the attack of the Spaniards, were conveyed to the bastions in wooden wheelbarrows, having a layer of sand between them and the balls.

Fluids are very imperfect conductors of heat, as may be satisfactorily shewn by different experiments.

Ex. 11. Fasten down a piece of ice to the bottom of a glass jar, about twelve inches deep and four inches wide; having covered the ice to the depth of four inches with water, at the temperature of 32° , place a wooden box, perforated with small holes in its sides, on the surface, and then pour boiling water very carefully and slowly upon the bottom of the box, until the jar is nearly full. The ice will remain unmelted for some length of time; proving that heat is very slowly conducted by the cold water first placed over the ice.

Ex. 12. The same fact may be proved, by placing in a similar jar, *a*, fig. 10, a small air thermometer, *b*, which is merely a glass bulb with a short tube open at the end, a portion of air being expelled by warming the bulb with the hand; the tube is dipped into some coloured fluid, a small quantity of it enters into the tube, the instrument is then ready for use. Being immersed to the depth of an inch, or an inch and a half, below the surface of the water, it will be but very little, if at all, affected by inflaming ether on the surface of the water. It will be seen, on taking the instrument out of the water, that the smallest addition of heat applied to the bulb, will expand the air within, and force the liquid down in the tube.

Water is so imperfect a conductor of heat, that an opinion prevailed for some time of its being an absolute non-conductor; the small quantities of heat which were found to advance downwards in such experiments as have been described, were supposed to be conducted downwards by the sides of the vessels in which the experiments were performed. The subject was set at rest by Dr. Murray, who used a vessel made of ice for the experiment. In this way no heat could possibly pass downwards by the sides of the vessel, because all the heat applied at the surface would only tend to melt the ice there. In this form of the experiment, as small portions of heat did descend, it was proved that water has conducting power in a very small degree.

Air is a very imperfect conductor, heat passing through it with considerable difficulty. It is to this property of air that we are in a great measure indebted for the warmth of our clothing in winter. The warmest articles of clothing are those which have the longest nap, or fur, or down; chiefly on account of the air which is involved among the fibres, or hairs, or feathers of which such substances are composed.

Count Rumford entered into an experimental investigation of this subject. He suspended a thermometer in a cylindrical glass tube, having a bulb at one end rather less than two inches in diameter, the bulb of the thermometer being

exactly in the centre of the larger one. In order to ascertain the relative powers of bodies to confine heat in other bodies, the thermometer bulb was surrounded with the substance to be submitted to experiment, and then placed within the larger bulb. Thus prepared, the apparatus was heated by being plunged into boiling water, and was afterwards cooled by immersion in a mixture of pounded ice and water; the number of seconds which were required in each experiment to cool the thermometer from 70° to 10° of Reaumur were carefully observed: the results which were obtained are here introduced. In most of the experiments the same weight of each substance was submitted to examination. The length of time required for the cooling of the thermometer through the above-mentioned range of temperature was, when it was surrounded with air, 576 seconds; with raw silk 1284"; ravellings of taffety 1169"; sewing silk cut 917"; wool 1118"; cotton 1046"; fine lint 1032"; beaver's fur 1296"; hare's fur 1315"; eider down 1305"; charcoal 937"; lamp black 1117"; wood ashes 927".

It will be seen that the results obtained by the experiments upon silk in different states, the raw silk, ravellings of taffety, and cut sewing silk, that the conducting power was least of that portion which was most twisted, or, in other words, the most dense; from which it may be inferred, that the cause of the inferiority of conducting

power belonging to these substances does not depend upon the difficulty opposed to the passage of heat by solid matter, for the most dense or solid portions of silk are the best conductors. The effect, as has already been noticed, is attributed to the air; but as these substances are much worse conductors of heat than air itself, it has been conjectured that the difficulty opposed to the escape of heat is occasioned by the interruption presented by the numerous fibres of the substances in question to the agency of the air, by the motion of which it would otherwise be more readily cooled. The force of attraction which these substances are capable of exerting for air is also believed to be instrumental in some degree in preventing the cooling effects which would result from the motion of air. There is this great difference between confined and unconfined air, that the former resists the escape of heat, while the latter greatly promotes it; this will be farther explained when reference is made to the different ways by which heated bodies are cooled.

The effect of confined portions of air in preventing the escape of heat may be observed in double windows, which are constructed for that purpose. It is to the air involved among the particles of snow, that the important agency of snow in preserving the roots of plants from being injuriously cooled is chiefly ascribed.

Latent Heat.

Dr. Black first discovered that all bodies contain a portion of heat which is neither sensible to the touch, nor capable of being detected by the application of the thermometer, and he called it latent or concealed heat. Bodies require more or less of this kind of heat according to circumstances. In general, when a body undergoes any change which enables it to exist in less room, a portion of its latent heat is rendered superfluous, and being set free becomes sensible heat. When large plates of brass are placed between steel dies, and stamped with great force into particular shapes, a single blow compresses a piece and renders it hot, as if its latent heat had been forced out; and it is remarkable that it cannot be struck again without danger of breaking it, until it has been put into the fire, and very much heated in that way; when cold it is fit to be applied to the dies again, as if the heat from the fire had entered into it, becoming latent, and rendering it fitter to receive the impression of the die.

Ex. 13. Fill one small wine glass with water, and another with sulphuric acid, then carefully mix these quantities in a larger vessel; the mixture will become so hot, that if it is stirred with a test tube containing ether, the ether will boil violently. On measuring the bulk of the liquid

after the mixture, it will be found less, not then being sufficient to fill the two wine glasses; which shews that condensation ensues on the mixture; the fluids are made to exist in less space, and latent heat being in consequence set free, becomes sensible heat, and produces the effect described.

When bodies undergo any alteration which enables them to occupy more space, it is then necessary that sensible heat should enter into them, and become latent. Thus, before water can be converted into steam, sensible heat must pass from the fire into it, and become latent; every quantity of steam arising from boiling water, containing at least 1000° of caloric thus changed and concealed.

The evaporation of liquids produces cold on this principle; a liquid cannot be converted into vapour before sensible heat enters into it in sufficient quantity to supply the vapour with latent heat, which occasions great reduction of temperature. Thus the water of showers in summer, in evaporating withdraws great quantities of heat, which occasions the earth and the air to be cooled and refreshed.

Ex. 14. The instrument called an air thermometer will strikingly illustrate the production of cold by evaporation. It consists of a bottle containing some coloured water, and a long tube with a bulb at one end of it: there is also a scale

divided into one hundred equal parts, fig. 11. The tube being passed through a cork, and immersed in the coloured fluid, a warm hand is applied to the bulb, the heat of which expands the air, and forces a portion of it to escape; when the air cools again it contracts in bulk, and the pressure of air on the surface of water in the bottle forces a portion to ascend, and fill the space which was before filled with air. The surface of the liquid column in the tube will then be prepared to indicate the slightest changes of temperature; heat, by expanding the air, making it descend, and cold, by contracting the air, permitting it to ascend. When the instrument is prepared, as in fig. 11, the liquid column standing about half way up the tube, a little ether poured on the bulb so as to spread over it will quickly evaporate, but it cannot evaporate until sensible heat enters into it becoming latent; one part of the heat required being taken from the surrounding air, another from the glass bulb, and a third from the air within the bulb; the loss of heat occasions that portion of air to contract, by which the pressure upon the surface of the fluid in the tube is lessened, so that the pressure upon the outside is enabled to raise it much higher. The quantity of heat withdrawn, or in other words the degree of cold produced, is estimated by the height to which the fluid rises.

The sensation of intense cold, produced by

pouring a little ether upon any part of the skin, is occasioned by the sensible heat of that part entering into the ether and becoming latent, to enable it to assume the state of vapour.

The effects of perspiration are forcibly illustrative of the rapidity with which heat is withdrawn by evaporation. The natural temperature of the human body is from 96° to 98° , but active exercise or exposure to great heat, occasions a tendency to a rise of temperature, which if not counteracted would be highly injurious. As soon as this tendency begins to be manifested, a watery fluid comes to the surface of the skin, that by its evaporation the body may be cooled and preserved at the healthy temperature; and so great is the power of perspiration in keeping the body harmless, under apparently dangerous circumstances, that persons have submitted, without injury, to be surrounded by air hotter than boiling water, as in the experiment tried by Sir Joseph Banks and Sir Charles Blagdon, and recorded in the *Philosophical Transactions*. These gentlemen went into an apartment, prepared for their reception, by Dr. Fordyce, in which the heat of dry air was gradually increased until the thermometers in the room indicated a degree of heat 52° higher than that of boiling water. Eggs were boiled hard in water heated only by the heat of the room, and slices of beef placed upon iron plates were rendered fit to be eaten in thirty-three minutes.

Bodies cannot change from the solid to the fluid state before sensible heat enters into them, becoming latent; which may be illustrated by the following experiment.

Ex. 15. Put a pound of new fallen snow into a glass vessel, and add to it a pound of water, heated to 172° , and rapidly stir the mixture; the snow will suddenly be dissolved, and the temperature of the whole mixture sinks to 32° . 140° of heat instantly disappear, for the purpose of enabling the snow to assume the fluid form of water. Hence the caloric required to enable a solid body to assume the fluid form, or as it is called the caloric of fluidity, is 140° . Many other experiments have been tried on the melting of different bodies: all tend to confirm the same fact; so that it is accounted a law of nature, that when solid bodies become fluid, sensible caloric combines with them and becomes latent.

It is on account of the large quantity of heat, that is required to undergo this change, before ice and snow can melt, that the melting is so slow and gradual, and as the same quantities must be set free before water can freeze, the process of solidification is very much and beneficially retarded.

The temperature at which water boils and is converted into vapour, depends upon the degree of pressure to which it is subjected; at the usual pressure of the atmosphere, it boils at the heat of

212°, according to Fahrenheit's scale, but requires less heat in proportion as the pressure is diminished. On ascending the side of a high mountain, the higher we ascend the less heat water will require to make it boil; because, when we ascend the side of the mountain we leave beneath us a part of the column of air that occasions pressure; the higher we ascend the more of the aerial column we leave beneath, the more the pressure on the surface of water is reduced; and, consequently, the less heat it requires to make it boil. The same fact may be proved in different ways.

Ex. 16. Into a narrow glass jar, capable of holding a pint, put half a pint of water, near the boiling heat, and place the jar under a glass receiver on the plate of an air-pump. As soon as the air begins to be exhausted, the pressure on the surface of the water will be lessened, it will begin to boil, and will, if the exhaustion is sufficient, continue boiling until it comes nearly to the temperature of the air.

Ex. 17. Take a clear glass flask with a long neck, and adapt a cork to it, by covering it with sealing-wax, so that when the cork, *a*, fig. 12, is put into the hot flask, *b*, the sealing-wax may cover the edge, and effectually close the aperture; fill the flask about one-third with water nearly boiling, and apply the heat of a lamp; after the water has boiled for several

minutes, air will be expelled from the flask, and it will be full of steam; then apply the cork covered with sealing-wax, without pressing it close until the wax is softened, it must then be pressed in close, and the flask must be quickly removed from over the lamp. On plunging the flask into the jar of cold water, *d*, it will again begin to boil, and will continue boiling with violence; if the flask be removed from the cold water and plunged into boiling water, the water within will cease to boil; but if plunged into the cold water again it will again boil, and will continue boiling until it is nearly cold. In this experiment water boils by the application of cold, and ceases to boil by the application of heat. When the flask is effectually closed and plunged into cold water, the steam which constitutes a pressure upon its surface equal to the pressure of the air, is entirely condensed by the coldness of the water in the jar; so that the water within the flask being relieved from pressure boils, although the heat is so exceedingly reduced; but when the flask is plunged into boiling water, the heat occasions the formation of a portion of vapour within the flask, which exerts sufficient pressure to prevent the water, now much cooled, from boiling; the renewed application of cold water condenses this vapour, and permits the fluid to boil until it is nearly cold.

It appears from this and also from the preceding

experiment, that if it were not for the pressure of air, water would not continue in the liquid state, but would assume the state of vapour at a very low temperature.

To ascertain the quantity of sensible heat required to become latent in the formation of vapour, the following experiment may be tried.

Ex. 18. Put into the boiler, *a*, fig. 13, a given quantity of water at an ascertained temperature, and apply the heat of a spirit-lamp well supplied with spirit of wine, and mark the time required to raise the water to the boiling point; then continue the application of the same heat until all the water is converted into steam, and the quantity required will appear sufficient to raise the water (were it capable of remaining as water under such circumstances) at least 1000° above the boiling point; and as no part of the steam, when allowed to escape, indicates a temperature greater than that of boiling water, the whole of the quantity that enters into combination after the water arrives at the boiling point must assume the latent state.

Ex. 19. The same result may be arrived at in another way. Add to a gallon of water, at an ascertained temperature, one pint of boiling water, and mark the increase of temperature in consequence. Another gallon of water at the same temperature being prepared, a pint of water put into the boiler, *a*, fig. 13, and brought

to the boiling point; the boiler is then connected with a worm, properly prepared for the experiment, and immersed in the gallon of water to be heated; the whole of the pint of water is then to be converted into steam, and passed into the worm, which will thus receive the heat, and impart it to the water intended to be heated. In this manner it will be found that the heat produced by one pint of water entering in as steam will be about five times as much as that produced by the addition of a pint of boiling water.

Radiation of Heat.

It has been ascertained by the investigations of Lambert, Saussure, Pictet, Leslie, and others, that, when heated bodies are exposed in space, a considerable proportion of their excess of heat is projected from their surfaces in right lines into space all round about them; and that these heating rays, although invisible, are capable of being affected by polished surfaces on which they are permitted to fall, in the same manner as the rays of light. The apparatus used by Saussure and Pictet to prove these properties of heat, consists of two concave reflectors of polished tinned iron plate, *b* and *c*, fig. 14, each one foot in diameter, with a focal length of four inches and a half; these were placed exactly opposite to each other, at a distance of twelve feet two inches. A ball of iron, two inches in diameter, *a*, heated

so as not to appear luminous in the dark, was placed upon its stand in the focus of one of the reflectors; while the ball of a mercurial thermometer, *d*, was placed in the focus of the other reflector. In this situation, the temperature of the thermometer increased in six minutes from 4° of Reaumur's scale to $14\frac{1}{2}^{\circ}$. By this experiment it was proved that invisible rays of heat proceeding from the ball, *a*, being intercepted by the reflector, *b*, were then reflected in straight lines through space towards the reflector, *c*; which also intercepted the rays, causing them to converge to a focus upon the bulb of the thermometer, *d*, which was in consequence considerably heated.

On trying this interesting experiment, it will be found convenient to use the air thermometer, fig. 11, instead of the mercurial one; and to prove that the instrument is not affected by heat proceeding directly from the side nearest to it, a piece of thick glass plate may be held between the thermometer, *d*, and the reflector, *c*, which will prevent any effect from being produced; or if the plate glass be held between the reflector, *b*, and the heated ball, *a*, it will equally prevent any effect from being produced upon the instrument: clearly proving that the thermometer is affected only by the rays which proceed in the direction before pointed out; namely, from the ball, *a*, to the reflector, *b*, from the reflector, *b*,

to the reflector, *c*, and from that to the bulb of the thermometer, *d*.

It has been found that heat quits the surfaces of different bodies with very different degrees of velocity; or, in other words, that different bodies have very different degrees of radiating power. Mr. Leslie covered one side of a six inch cubical vessel of tinned iron with lamp black, another side with writing paper, a third with glass, and left the fourth side uncovered; he then filled the vessel with boiling water, and placed it upon a stand, *a*, fig. 15, opposite to a highly polished concave reflector, *c*, having a differential thermometer, *b*, placed in its focus. When the black side was turned towards the reflector, a rise of temperature was produced in the thermometer equal to 100° ; the papered side being turned to the reflector produced a rise of temperature equal to 98° ; the glass side raised the temperature of the instrument 90° ; and the bright metallic side only 12° .

In the same way the radiating powers of other substances were ascertained. The following table will shew the results of several experiments.

The radiating power of the after-named substances, under the circumstances already described, compared with each other, are—

Lamp black	100°
Writing paper	98
Sealing wax	95
Crown glass	90
China ink	88
Red lead	80
Plumbago	75
Isinglass	75
Tarnished lead	45
Clean lead	19
Iron, polished	15
Tin plate	12
Gold, silver, and copper . . .	12

A knowledge of this difference in the power of different bodies to confine heat, or permit its escape, suggests the propriety of using vessels with bright metallic surfaces when heat is to be confined, and vessels with black surfaces when it is desirable that it should escape with facility.

Thus in applying the heat of steam to warm the air of an apartment, it would be absurd to use black pipes to convey the steam to the place of its destination, because such pipes would permit too much of the heat to be lost by radiation ; and it would be equally improper to place bright pipes round the room for the purpose of diffusing the heat of the steam, as such pipes, having very little radiating power, would confine the heat and

defeat the object in view. It would be proper to use bright pipes for conveying the steam, and black ones for diffusing its heat through the apartment.

Surfaces that radiate heat rapidly, also receive or absorb it with rapidity. Thus a metallic vessel placed over the fire, receives heat more rapidly after its surface has been blackened than before. Surfaces that are slow in radiating heat are also slow in receiving it: the best fire-screen, therefore, is that which has a bright metallic surface.

Heated bodies exposed to the air, not being in contact with conducting substances, lose their heat in two different ways; about one half being lost by the process of radiation, previously described, the other half being carried away by the agency of air. Successive portions of air coming into contact with a hot body, they are heated, expanded, and consequently they ascend. This fact may be strikingly shewn with the aid of an air thermometer, fig. 11. The bulb of this instrument being held at a little distance under a heated ball, properly supported, it will be very slowly affected, because below the ball there will only be the heat which is radiated from that part of the ball immediately above the thermometer: but when the bulb of the instrument is held at the same distance above the ball, it is so much affected that the surface of the liquid column rapidly descends and disappears.

LIGHT.

When a pencil of rays of light is admitted through a hole in the window shutter, in a darkened room, and made to fall upon a triangular prism of glass, it is turned out of its natural course, and prevented from falling on the floor, where it would have produced a spot of white light, instead of which it forms a spectrum of splendid colours on the wall, or on a screen placed to receive it; the cause of this is the refrangibility of light. On being made to pass through the dense medium of the glass prism, it is bent out of its natural direction; thus, Sir Isaac Newton discovered that light is a compound; for some of the rays of which it is composed being more refrangible than others, that is to say, being more capable of being bent out of their natural course, they fall upon the screen farther from the direction in which they would have proceeded had not the prism been interposed. The rays of compound light are therefore separated from each other, and exhibited distinctly by this process; because the rays of light that are least refrangible, being least bent out of their natural course, fall upon the nearest part of the screen, while the more refrangible rays being more bent out of their natural direction, fall upon a part of the screen more distant from their original course. The most refrangible rays are of a

violet colour, then indigo, blue, green, yellow, orange, and red; the red rays being the least refrangible. A moment's inspection of fig. 16, will more clearly explain this interesting experiment. *a*, represents the hole in the wall, *b*, through which the pencil of rays finds entrance to the glass prism *c*, *d* the screen, with the diverging rays or coloured spectrum falling upon it. 1. The violet, or the most refrangible ray; 2. The indigo; 3. The blue; 4. The green; 5. The yellow; 6. The orange; and, 7. The red or the least refrangible ray: *e*, is the direction which the light would have taken, if it had not been intercepted. Sir Isaac Newton having thus proved that light is compounded of several different coloured rays, founded, upon this decomposition, his theory of the colours of bodies in general; according to this theory, bodies do not possess colours as qualities inherent in them, but in all cases derive their colour from the decomposition of light; bodies having the power of absorbing some of the rays of light and of reflecting others; the ray that is reflected gives colour to the substance, green if the ray is green, red if the ray is red.

The statement of these phenomena implies that light is material; that this is the case seems to be proved by the following considerations; although it moves through a space with a rapidity almost inconceivable, it may be stopped in its progress, or it may be compelled to change its

direction ; it may be condensed into a smaller or diffused over a larger space ; when passing near to any body it inclines towards that body, which proves that, like other matter, it is subject to the force of gravitation.

The opinion respecting the nature of light which was maintained by Descartes, Huygens, and many other philosophers, is, that its phenomena are occasioned by vibrations, which they imagined luminous bodies have the power of exciting, in a very rare and elastic medium supposed to extend through all space ; much in the same way as sound is produced by vibrations in the air. The theory of Newton, however, has been more generally adopted ; according to this theory, material particles, of extreme minuteness, are believed to emanate from the sun and other luminous bodies, moving through space with exceeding velocity in right lines. When we consider that every body which is visible to us, except the sun and stars, is rendered visible by light reflected from its surface, it will be obvious that the visible universe must be filled with rays crossing each other in every direction without interruption, we shall be enabled to form some idea of the exceeding minuteness of the particles of which these rays are composed, and of the great distance existing between them. That the particles of light are exceedingly minute may also be inferred from the velocity of their motion,

which is estimated at nearly 200,000 miles in a second of time. The force or momenta with which moving bodies strike against other bodies, being as their weight multiplied by the velocity, if the particles of light were of any calculable size, they would destroy every thing in their progress; but they are so inconceivably small as to be capable of impinging upon the eye, without doing it injury. An *attempt* was made to estimate the momentum of light by letting the accumulated rays, collected by a large concave mirror, fall upon an exceedingly delicate weighing apparatus, from which it was inferred that the whole matter in the rays of light, collected by a concave mirror, two feet in diameter, did not amount to more than one twelve hundred millioneth part of a grain!

Light is attracted by some bodies and combines with them without decomposition, for it is capable of being emitted again unaltered. Bodies possessed of this property are termed solar phosphori; these substances, on exposure to the solar light, imbibe portions of it which are again emitted when the substances are removed into the dark. One of the first observed, and most remarkable bodies of this kind, is called the Bolognian stone, (a variety of sulphate of barytes). Numerous substances are found to emit light in a dark place after exposure to the sun's rays. The shells of marine, and the bones of land animals, fluor spar, limestone, and some of the

gems; sugar, and white paper, all possess this property in a considerable degree. But the most powerful solar phosphori are artificially prepared; there are several of them, but Canton's phosphorous is the best. It is prepared in the following manner:—Clean washed oyster shells are to be exposed to a red heat, in a common fire, for half an hour: the purest parts are then to be selected, and put into a crucible with alternate layers of sulphur—the mixture is to be pressed down until the crucible is nearly full, and it must be exposed to a red heat for at least an hour; when it is cold the mass must be broken, and the whitest parts selected for use. It is sufficient to expose such phosphorus to clear day light, to render in highly luminous in the dark; it may also be rendered luminous by an electrical discharge. Phosphorescent bodies of this kind shine brighter when they are heated; but their light is sooner exhausted. It appears easier to reconcile the appearances which these bodies present to the Newtonian theory of light, than to that by which vibration is supposed to be the cause of illumination.

There are other bodies which become luminous when heated, without previous exposure to light, which soon lose this power by being heated, and cannot recover it by subsequent exposure. Fluor spar is the most powerfully phosphorescent body of this kind. When broken into small pieces,

and thrown upon a plate of iron, heated to dull redness, it gives out a beautiful light of different colours. A fire shovel answers well for this experiment. Some bodies may be rendered phosphorescent by friction, as two pieces of quartz rubbed together in the dark.

Another variety of phosphorescence belongs chiefly to animal matter, sometimes in a living, but mostly in a dead state; it is most remarkable in marine animals: the phosphorescence of fishes is said to be the strongest a short time after death, before putrefaction is far advanced. It has been found that the luminous matter may be separated from the body of the animal, by immersing it for a short time in dilute saline solutions; such as common salt, sulphate of magnesia, sulphate of soda, nitre, and several others. Fresh water destroys the luminous property, as also does spirits of wine, and saturated solutions of the same salts which promote the light when used in dilute solutions. Agitation, gentle heat, and oxygen gas increase the brightness of the phosphorescence; while great heat, cold, most of the gases, and the vacuum of an air pump, extinguish the light. The beautiful phosphorescency of sea water is supposed to be occasioned partly by the solution of luminous animal matter, and partly by the presence of phosphorescent animalculæ. Decaying vegetable substances, such as wood, sometimes emit a light, very

similar to the phosphorescence of animal matter ; the same remark may be made respecting some examples of chemical action, as when pure potash, lime, or magnesia, is brought into contact with the mineral acids, light, resembling phosphorescent light, is emitted.

One variety more of phosphorescent light requires to be noticed in this place—it is that which is given out in large quantities by insects, such as the glowworm, and the lantern-fly of the West Indies. The matter which possesses the shining quality in insects of this kind is usually liquid, and is capable of having its brightness increased by warmth or friction. A thermometer held in the different coloured rays of a prismatic spectrum, is most heated in the red ray, and least in the violet ; it is also heated on the outside of the red ray, where there are no visible rays ; from which it appears that light and heat are not the same, although they accompany each other, and are very closely connected. It is, indeed, difficult in some cases to separate the ideas and the phenomena of light and heat. When the rays of the sun are collected together in the focus of a burning-glass, the heat produced will always be in proportion to the brightness of the rays, and the conclusion seems to be irresistible that they are one and the same. But it has been proved by Herschel and other philosophers, that the rays of light which are separated from each

other by the prism, in consequence of their different refrangibility, are accompanied by rays of heat less refrangible than themselves, and which are therefore found nearer the original direction of the light before it was intercepted by the prism. If, as Herschel imagined, the hottest part of the spectrum had been on the outside of the red ray, no doubt could have remained on this subject; but those who have repeated the experiment found the maximum of heating power in the red ray, and not beyond it: the subject is still involved in some uncertainty. It is admitted, however, that there are invisible heating rays on the outside of the red ray, although their heat is not greater than that of the red ray. The existence of these rays in that situation, whatever their degree of heat may be, seems to prove that the rays of light are associated, not combined with rays of heat of less refrangibility. The rays of heat themselves, being differently refrangible, being spread over the spectrum, seem to impart different heating powers to the different coloured rays, which of themselves they do not possess.

The different refrangibility of the rays of heat and light was proved by the experiment of Herschel, in which he found the heat of a concave mirror farther from its surface than the focus of light.

The separate existence of heat and light is also shewn by placing a large piece of transparent

glass before a fire, the heat will be intercepted, but the light will pass through, and may be collected into a focus, in which there will be no sensible heat.

Light exerts a powerful influence in effecting chemical changes, chiefly by separating oxygen from combinations, where it is not held by very strong affinity; thus, nitric acid exposed to the light, assumes a yellow hue, which arises from the loss of a part of its oxygen. Light strongly affects many of the compounds of metals with oxygen, and sometimes decomposes them. Paper moistened with solution of nitrate of silver, on exposure to light is soon blackened, and the muriate of silver is still more sensible to the influence of light. Scheele dissolved the mass obtained by evaporating a solution of gold to dryness, in a phial of distilled water, and closing it with a glass stopper, exposed it to the rays of the sun; and in a fortnight after, minute spangles of gold appeared in the solution, and the surface was covered with a fine pellicle of gold. Mrs. Fulhame dipped a piece of silk in a solution of muriate of gold in water, and exposed it to the sun, keeping it moist; the silk changed successively from yellow to green, purple, and, in about an hour, to a bright gold colour; its whole surface being covered with a superb coating of reduced gold. The operation of bleaching by exposure to light and air, affords another example of the chemical agency of light.

In vegetation we obtain a clear view of the influence of light upon plants, in the processes of the gardener, for making lettuces, endive, and celery, white and tender. As soon as light is excluded from them this effect is produced; it is supposed by the accumulation of oxygen in the plants, derived, perhaps, from the decomposition of water: when light is again admitted to them, the excess of oxygen, by its influence, is withdrawn, and the plants recover their green colour again.

ELECTRICITY.

Electricity possesses great power as an agent in effecting chemical changes. In order to illustrate this agency, it will be necessary to explain, in this place, some of the principal phenomena of electrical science. When a wide tube, or any other convenient piece of glass, is warmed and rubbed with a piece of dry silk, it acquires the property of first attracting, and then repelling light substances, such as small pieces of gold leaf, particles of tissue paper, or down of feathers; sealing wax, rubbed with flannel, produces similar appearances; and warm dry writing paper, rubbed upon a table with Indian rubber, will, when it is separated a little from the table, draw light substances under it, and afterwards repel them from its surface. There is, however, a very remarkable difference between the effects pro-

duced by rubbed glass and rubbed sealing wax; for if a very light feather is suspended by a thread of silk, a piece of rubbed glass held near it, will first attract and then repel it, another piece of glass also excited by friction being held near, will repel the feather still more; but a piece of rubbed sealing wax will attract the feather that is repelled by the glass: and if the feather be brought near a piece of rubbed sealing wax in the first instance, it will be attracted and then repelled, another piece of excited sealing wax will increase the repulsion, but a piece of excited glass will immediately attract the feather. By this experiment it appears, that the sealing wax attracts when the glass repels, and that the glass attracts when the sealing wax repels. They neutralize or destroy each others effects therefore; hence it was supposed that there are two electricities, which were called the vitreous, from glass, and the resinous, from sealing wax. Dr. Franklin explained the appearances differently: according to his theory, when glass is rubbed with silk, the glass, having a greater attraction for electricity than the silk, a portion of that which belonged to the silk is transferred to the glass, which is then electrified positively, having acquired more than its natural share of electricity; but when a piece of sealing wax is rubbed with a piece of flannel, the sealing wax, having less attraction for electricity than flannel has, a portion

of that which belongs to the sealing wax is transferred to the flannel, and the sealing wax is then negatively electrified, having lost a portion of its natural share of electricity. There is a strong tendency in electricity to a balance or equilibrium; thus if one light body be electrified negatively, and another positively, when they are brought near to each other, if they have freedom of motion, they will attract each other, that the body which has more than its natural share, may impart its superfluity to that which has less, and the balance or equilibrium be restored. On these principles, the phenomena of the glass, sealing wax, and feather, admit of easy explanation. A piece of excited glass brought near the feather attracts it, because the glass being overcharged, and the feather being in its natural state, it is attracted by the glass, that it may receive a portion of the electricity with which the glass is overcharged, and help to restore the equilibrium; but when the feather comes into contact with the glass, and is overcharged in the same degree, since bodies that are unequally electrified, attract one another, that there may be an equal diffusion of electricity among them, the feather being overcharged is attracted by the air, which makes it appear to be repelled by the glass.

The distinction between positive and negative electricity may be farther illustrated by reference to a cylindrical machine with two conductors,

fig. 17. *a* is a glass cylinder, which is made to revolve against a cushion, fixed upon *b*, the negative conductor, seen through the cylinder, having the silk flap, *d*, attached to it; *c* is the positive conductor, supported upon a pillar of glass, and having sharp points on the side next the glass, for the purpose of receiving electricity; *e* is the glass pillar of the negative conductor, which is fastened into a sliding socket, that the cushion may be adjusted to the cylinder, so as to occasion more or less friction.

When the cylinder, *a*, revolves against the cushion, which is smeared with an amalgam of tin, zinc, and quicksilver, the glass, exerting a superior degree of attraction for electricity, takes away a portion of what belongs to the rubber, and the conductor to which it is attached, which renders the conductor negative; while the electricity taken away, being conveyed to the conductor, *c*, it is positively electrified: and a pith ball supported upon it, will attract a pith ball upon the other conductor, and be attracted by it as at *f*.

Although the phenomena of chemical attraction and decomposition may be exhibited by electricity, excited in this way, yet not so easily or so powerfully, as by that which is excited by the voltaic apparatus, and known by the name of galvanism.

This active chemical agent was accidentally discovered by Galvani, an Italian philosopher,

who observed its effects upon the animal frame, in 1791. The most satisfactory explanation of this remarkable effect was given some time afterwards by Volta, another continental philosopher, who having discovered that different metals attract electricity with different degrees of force, founded his explanation upon this discovery. When a small animal, recently killed, such as a frog, is touched in different parts by two pieces of metal of different kinds, say silver and zinc, as soon as the metals are made to touch each other at their ends, farthest from the animal body, the zinc attracts a part of the electricity belonging to the silver, and the deficiency being supplied from the animal body, the convulsive appearances are occasioned by the disturbance of the electrical equilibrium.

It occurred also to this philosopher that it might be possible to arrange pieces of metal of different kinds, in such a way as to produce a much greater effect, which led to the construction of the voltaic pile. *a*, fig. 18, represents an arrangement of this kind, one plate of each metal, silver and zinc, being placed upon a stand within glass rods; a piece of moistened cloth, or card, is put over them, then a plate of silver and a plate of zinc, and another piece of moistened cloth; a tall pile of these metals being raised in this order, wires proceeding from the two extremities of the pile, being brought into contact with the body

of a small animal, occasioned a much greater degree of agitation than had been produced before. The invention was no sooner made known to the British philosophers, by a letter from the inventor to Sir Joseph Banks, in 1800, than they commenced experiments which produced very important results. Messrs. Nicholson and Carlisle discovered, that when the wires proceeding from the two ends of the pile, were made to terminate at a little distance from each other, in a tube containing water, as is shewn at *b*, fig. 18, a portion of the water was decomposed into an explosive compound of its constituent parts, oxygen and hydrogen. The voltaic pile was shortly after modified and improved for most experimental purposes, by Mr. Cruickshanks, who arranged the plates, two and two, perpendicularly in wooden troughs, fig. 19. This construction permitted dilute acids to be poured into the cells, so that the plates were acted upon more energetically, and some of the effects resulting from this action were proportionably greater. The plates were afterwards attached to a piece of wood, and made moveable, that they might admit of being removed from the action of the acid, in the cells of the trough, which was at first supplied with glass partitions; troughs of earthenware, with divisions of the same kind, were afterwards introduced, and are now in very general use. The last improvement to be ad-

verted to in this place, is that introduced by Dr. Wollaston, who found that a larger surface of copper than was usually employed, greatly increased the power of voltaic plates. Instead of opposing a plate of copper to each plate of zinc, a plate of copper is made to envelope each plate of zinc entirely. The powers of voltaic combinations were most successfully investigated by Sir H. Davy, on whose labours and discoveries the science of electro-chemistry is chiefly founded. Pursuing the discovery of Carlisle and Nicholson, he submitted to the voltaic wires two portions of water in separate vessels, connected together, and he found that hydrogen was evolved from the one, and oxygen from the other. By the success of this experiment, he was led to expect that the constituent parts of other bodies might be disunited by the same agency, and exhibited separately. Numerous bodies were submitted to the test of this examination, and the results constitute the most important discoveries of modern times. The attractive force of the voltaic wires for the particles of compounds is such, that the constituent particles not only of fluid compounds, but those also of the most solid aggregates are separated from each other; marble, gypsum, fluor spar, sulphate of barytes, and even glass itself, are decomposed, when moistened and brought into contact with the voltaic poles. Acids and alkalies are not only separated from

each other, but acids may be made to pass through alkalies, and alkalies through acids without combining. Metals, inflammable bodies, oxides, alkalies, and earths, are attracted by the wire proceeding from the negatively electrified end of the battery; and the wire from the positively electrified end attracts oxygen, chlorine, iodine, and acids. The astonishing effects of this agency may be impressed upon the mind by the description of a few experiments.

If a thin piece of solid hydrate of potash be placed between two pieces of platinum, and brought into contact with the wires proceeding from the ends of a voltaic battery, consisting of two hundred pairs of plates, four inches square, it will quickly be fused, oxygen will be evolved at the end of the positive wire, and small brilliant globules of potassium will be produced at the end of the negative wire. In this way the metal was discovered by Sir H. Davy, in October, 1807.

Ex. 20. The decomposition of many compounds may be effected by a much smaller apparatus. Fig. 20 represents an experiment for proving the decomposition of a compound of acid and alkali. The glasses, *a a*, contain a solution of sulphate of soda, and are connected together by the little glass syphon tube, *b*, which is filled with the same liquid; *c c*, are two glass tubes being suspended upon the wires of the stand, *d d*, by

platinum wires, which pass through corks in the upper ends of the tubes down to their lower ends, and the tubes are filled with the blue liquid obtained by infusing the leaves of red cabbage in boiling water; it is the nature of blue vegetable infusions to be reddened by acids and rendered green by alkalies; when the wires, *e e*, proceeding from the ends of a voltaic combination, are connected with the wires of the stand, *d d*, decomposition of the compound in the glasses will commence; the acid of the portion decomposed, will be attracted to the positive wire, and the blue vegetable infusion, through which that wire passes, will be changed into red; the soda of the decomposed compound will be attracted by the negative wire, and the blue infusion in contact with that wire will be rendered green. Thus, a convincing proof of the decomposition of the compound is obtained. If the position of the apparatus be altered, so that the tube which was first in contact with the positive wire, be brought into contact with the negative wire, and the tube which was in contact with the negative wire, be connected with the positive wire, the colours will gradually become dimmer and dimmer: for the alkali being attracted to the tube which was before reddened by the acid, the acid is neutralized by the alkali, and the liquid returns to its original blue; the alkali then begins to predominate and the liquid assumes a green colour.

In the same manner, acid being attracted to the tube which was first rendered green by an alkali, the alkali is neutralized by the acid, and the blue colour is restored; at this moment the acid begins to prevail, and the fluid that was green, becomes red.

Ex. 21. Fig. 21 represents the decomposition of a metallic compound: the glass, *a*, contains a solution of acetate of lead; the ends of wires from a battery, *b* and *c*, being immersed in the compound, the positive wire will attract the acid, by which, if it is a copper wire, it will be acted upon and partly dissolved; this occasions a green liquid, characteristic of a solution of copper, to accumulate on the surface of the liquid in the glass; the negative wire attracts metallic particles from the transparent liquid, and is soon covered by quantities of them of great metallic lustre.

Bodies that are attracted to the positive pole are called electro-negative, and those that are attracted to the negative pole electro-positive.

ELECTRO-NEGATIVE BODIES.

The electro-negative bodies are oxygen, chlorine, iodine, and bromine, to which is usually added the supposed base of fluoric acid, fluorine.

OXYGEN derives its name from Greek words, signifying *acid* and *I generate*, as it was then believed to be the only former of acids. It was first discovered by Dr. Priestley in 1774. It may

be obtained for the purpose of experiment in several different ways.

Ex. 22. Some black oxide of manganese in fine powder, being put into a glass retort, *a*, fig. 22 with sulphuric acid in sufficient quantity to moisten it thoroughly; when the heat of a lamp *b*, is applied to the retort, oxygen gas will be obtained, by immersing the neck of the retort in water, in the hydro-pneumatic trough *c*, underneath any vessel filled with the same fluid as the receiver *d*. The common air in the retort should first be allowed to escape.

Oxygen is obtained in great purity from chloride of potash, heated to redness in a small glass retort in connection with the hydro-pneumatic apparatus. Fig. 22.

Ex. 23. But the method by which it may be prepared, at a moderate expence, and in sufficient purity for experiment, is by putting oxide of manganese in small lumps into a wrought iron bottle *a*, fig. 23, fitted air tight with a long tube *b*; the bottle must be put into a common fire *d*, and when it has attained a red heat, a portion of the oxygen will quit the manganese, and pass through the tube into the vessel *c*, placed to receive it. The vessel *c*, is Pepy's improved gas-holder; it is usually made of copper, or of tinned iron, japanned inside and out, and is made to hold from two to eight or more gallons. In the bottom of the cistern *e*, there are two apertures, opening into the gas-holder below; the tubes connected

with these apertures are both furnished with stop-cocks; one of these tubes is prolonged downwards, inside the gas-holder, nearly to its bottom, the other tube merely opens into the top. When gas is to be prepared, the gas-holder is placed upon the shelf of a hydro-pneumatic trough, or, as it is represented at fig. 23, upon a board placed across a tub *f*; all the stop-cocks above being closed, the large plug at *g* must be unscrewed, and the tube from the bottle introduced into the aperture, the water will not be able to escape until the gas begins to enter; as soon as the gas passes over, it will ascend through the water to the top, taking its place there, and expelling the water below. When gas is to be transferred into a bottle or receiver, the cistern *e* must be filled with water, and the vessel that is to be filled with gas, must also be filled with water, and inverted over the aperture in the cistern that communicates with the top of the gas holder; both stop-cocks must then be opened, and the pressure of the water down the long tube will compress the gas against the top, and make it readily ascend by the open aperture into the vessel above. Or a flexible tube may be attached to the stop-cock *h*, and introduced under a jar upon the shelf of a hydro-pneumatic trough. The glass tube at *i* is inserted at top and bottom of the gas-holder, for the purpose of shewing the state of the inside, as to the quantity of gas.

Oxygen gas is a little heavier than common air,

100 cubical inches of it weigh 3.888 grains, and it is transparent and colourless, and has neither taste nor smell. Combustible bodies when ignited and plunged into this gas, burn with increased rapidity and splendour.

Ex. 24. When a taper is blown out and plunged into a bottle of the gas, if the wick remains ignited in the least degree, it bursts into a flame with a slight explosion.

Bodies that require the most intense heat of furnaces to melt them, melt readily when plunged into this gas.

Ex. 25. A long piece of iron wire, of that kind called binding wire, being turned into a spiral, round a stick or small bottle, if a small piece of cotton or rag, dipped in tallow, be attached to the lower end of the spiral and lighted, the wire will take fire when plunged into a considerable quantity of oxygen, and burn with brilliant scintillations, fig. 24; melted globules of an intense white heat, will run round the spiral, until they become heavy enough to fall down by their own weight. The heat of these globules is so intense, that after falling through an inch, or an inch and a half of water, they remain hot enough to melt the glass below, fixing themselves in its substance. In this experiment the iron combines with oxygen, and is converted into oxide of iron.

Ex. 26. To shew that oxygen gas is necessary in the process of burning, let two small pieces

of candle, one longer than the other, in two very short tinned iron candlesticks, be placed upon a flat dish with some water in it; over these candles when they are burning place a large glass receiver, open at the bottom, filled with common air, fig. 25; the receiver will almost instantly be coated with moisture on the inside, the candles will begin to burn dimly; the tallest will be first extinguished, and then the shorter one, while the water, more of which must now be poured into the dish, will be seen rising in the receiver, until it occupies about one-fifth part of the space within. In this experiment, hydrogen from the burning candles combines with the oxygen of the air within the receiver to form water, part of which is deposited on the inside of the receiver; the oxygen by entering into this new combination, is withdrawn from the air within the receiver, and as soon as it is exhausted in the upper part of the receiver, the tallest candle goes out; and when the oxygen in the lower part of the receiver is exhausted, the lower candle is extinguished also: the height to which the water rises within indicates that a very considerable proportion of the air has thus been changed or withdrawn; and the necessity of oxygen in the common process of burning is shewn.

Atmospheric air is composed of seventy-nine parts in every hundred of nitrogen or azote, and twenty-one of oxygen: these proportions have

been found the same in all situations, in cities and fields, on hills and in valleys, at sea and on land.

Oxygen is no less essential in the process of breathing than it is in that of burning; a small animal cannot live long when confined in a quantity of air, under a receiver; the oxygen is changed by the process of breathing, and the animal dies. A man of ordinary size requires from thirty to thirty-four ounces of oxygen in twenty-four hours; and when the bulk of this quantity of gas is estimated, it is found to exceed two hundred gallons! As the oxygen of atmospheric air constitutes but one-fifth part of the whole, it will be obvious that a man must breathe at least 1000 gallons of pure air, to keep him in health for twenty-four hours.

Since oxygen is necessary in such large quantities in the processes of burning and breathing, there must be some abundant sources of new supplies, for the purpose of repairing the waste of this vital principle. It has been, and is now believed by many eminent philosophers, that plants are instrumental in purifying the air which is rendered impure by the processes alluded to, for by these processes the oxygen of the air is changed into carbonic acid gas, which, if it were to accumulate, would render the air unfit for the purposes of life. Plants have the power of imbibing this poisonous gas, and of decomposing

it, for they retain the carbon of the compound to form a part of their own substance; and set free when acted upon by the sun's rays, volumes of pure oxygen gas to improve the deteriorated atmosphere. It is also believed that plants decompose water retaining the hydrogen and evolving the oxygen.

Oxygen is one of the most abundantly diffused substances in the universe, for beside many combinations of inferior importance, it forms, as has been stated, a fifth part of the air of the atmosphere, it constitutes, by weight, eight parts of nine in the composition of water; and it is a principle constituent part of the solid rocks that encrust the globe. Its atomic number or combining proportion is eight, compared with the combining weight of hydrogen, which is called one. Thus, when a portion of water is decomposed, the weight of the oxygen which it contains is eight, while that of the hydrogen is one.

Oxygen gas is also one of the most active agents in existence, covering the earth with variety by its numerous combinations, for it is capable of combining in different proportions with many of the simple substances, by which it occasions great variety of properties and appearances; and when it has entered into the composition of acids, it is again instrumental in producing, in a different way, another numerous

series of substances, possessing different properties and appearances.

The art of ascertaining the purity of atmospheric air, is called Eudiometry, and the instruments used for this purpose are called eudiometers: these are very numerous. There are also some substances used in this process, for the purpose of absorbing oxygen or other compounds into which the oxygen is made to enter; such as a mixture of sulphur and pearl ashes in water, or sulphur and lime that have been fused together. Dr. Henry recommends boiling a mixture of sulphur and quick lime together, filtering the solution, and agitating it for some time in a bottle half filled with common air. A solution of tin in muriatic acid, and a solution of sulphate of iron, into which nitrous gas has been made to enter, until the solution acquires a dark colour, are all used for this purpose. The simplest eudiometer is a graduated glass tube, fig. 26, divided into one hundred equal parts: it is filled with air, the purity of which is to be examined, and plunged into some liquid capable of absorbing oxygen, and suffered to remain there until all the oxygen is absorbed; the quantity of oxygen withdrawn will be measured by the rise of the liquid in the tube.

Ex. 27. Dr. Hope's eudiometer, fig. 27, consists of a small bottle, holding twenty or twenty-four drachms, with a stopper at *a*; the tube, *b*,

is fitted, by grinding, into the neck of the bottle; it is divided into one hundred equal parts, and holds exactly one cubical inch. To use the apparatus, the bottle is to be filled with the eudiometrical liquid intended to be used, one of the best is the above-mentioned solution from quick lime and sulphur; the tube full of the air to be examined must be put in its place, the inversion of the instrument occasions the gas to ascend into the bottle, where, being agitated repeatedly, the oxygen is absorbed. To supply the place of the gas absorbed, the apparatus must be turned tube upwards again, the bottle immersed in water, and the stopper taken out while under the water; these operations must be repeated as long as any diminution of the bulk of the air continues to take place. The bottle being then put under water, the tube must be taken out, and the height to which the water rises in it will indicate the quantity of oxygen absorbed. As there is some difficulty in managing this process well, on account chiefly of the necessity of supplying the place of the gas absorbed with water, Dr. Henry has substituted for the glass bottle one of elastic gum, fig. 28.

The quantity of oxygen contained in air may also be determined by mixing it with hydrogen, in a proper graduated tube, furnished with wires for the application of the electric spark: two measures of hydrogen being mingled

with three of air, and exploded. When the tube cools, the reduction of bulk observed must be divided by three, which will give the quantity of oxygen consumed.

Phosphorus is frequently used in the examination of air; a small piece, previously dried with blotting paper, is let up into a tube filled with mercury, and melted by holding a red hot iron near the glass; the air is then to be admitted, by a little at a time: the phosphorus inflames on every new admission of air. After the whole has been admitted, it is necessary to apply the hot iron again, to complete the absorption of the oxygen. The remaining air may then be transferred to a graduated tube, by which the loss will be ascertained.

The air jars, figs. 29 and 30, are highly useful for experiments on oxygen and other gases; the one is furnished with a glass stopper, to permit the introduction of substances to be burned in oxygen, and it has a flat dish underneath for transferring it from the gasometer, or the hydro-pneumatic trough, by holding water around it to prevent the escape of the gas; the other, fig. 28, is a graduated jar with a stop-cock, to which any vessel exhausted of air, intended to be filled with gas, may be applied, or to which a bladder may be attached for a variety of purposes.

CHLORINE was discovered by Scheele, in 1774.

Ex. 28. The apparatus, fig. 22, will answer very well for the preparation of this gas. Black oxide of manganese, in powder, being put into the retort, *a*, it must be covered with muriatic acid, and heated by a lamp; the gas will quickly be obtained in considerable quantities, but as cold water absorbs it more rapidly than hot, it is advisable to use hot water. In this process, the muriatic acid (which is composed of hydrogen and chlorine) is decomposed, by the affinity of the oxygen of the manganese for hydrogen, which unite, and chlorine is set free. The name of this gas is derived from a Greek word, signifying green, as the gas seen by day light is of a greenish yellow colour.

Chlorine is remarkable for its great weight: compared with hydrogen it is as 33.5 to 1; and one hundred cubical inches of it weigh nearly seventy-six grains. It is incapable of being breathed, and has an excessively disagreeable odour. A burning taper plunged into it continues to burn for a short time with a dull red light. Sulphur does not burn in it, but they unite, and a volatile red liquid is the result. Phosphorus, potassium, and sodium, and some other metals, in thin leaves or fine powder, as Dutch leaf, tin, arsenic, zinc, and antimony, take fire spontaneously, and burn with brilliancy in this gas.

Chlorine is not subject to change in conse-

quence of increased or diminished temperature ; but a solution of it in water freezes more readily than water.

Under great pressure it is capable of being condensed into a liquid ; a discovery recently made by Mr. Farraday, who having enclosed a portion of dried crystals of hydrate of chlorine in a small bent glass tube, which was hermetically sealed, the tube being heated to about 100° , a yellow vapour was formed, which condensed into a deep yellow coloured liquid heavier than water. On removing the pressure by breaking the tube, the liquid instantly assumes the state of vapour. Similar experiments were tried with success upon many other kinds of gas.

Water dissolves twice its bulk of chlorine, by which it acquires the power of destroying vegetable colours, and is the powerful agent now most generally used in the process of bleaching.

Ex. 29. Put a piece of cotton cloth, dyed with vegetable colour and moistened with water, into a small bottle of chlorine ; the colour will very speedily be changed into a yellowish white. The theory of the process is this : in consequence of the strong attraction of the chlorine for hydrogen, and of the colouring principle for oxygen, a portion of the water is decomposed, the hydrogen of which combines with the chlorine to form muriatic acid, while the oxygen that is set free combines with the colouring principle and destroys it.

Scarcely any effect would be produced upon the cloth if it were perfectly dry, the gas being dry also. But this mode of bleaching in the gas would not answer, because the muriatic acid produced in the process would attack the texture of the substance bleached, and injure it. To avoid this injurious effect, bleachers put a quantity of lime into their bleaching solutions of chlorine; the bleaching property is not impaired, while the lime combines with the muriatic acid that is produced, and prevents it from attacking the goods that are undergoing the bleaching process. Sir H. Davy recommends magnesia instead of lime.

Fumigation with chlorine is said to be the most powerful means of destroying contagious effluvia.

Chlorine combines with oxygen in four different proportions, producing two oxides and two acids. Its combining weight or proportion is 36. Thus in muriatic acid, which is composed of chlorine and hydrogen, the weight of the former, is to that of the latter, as, 36 to 1.

PROTOXIDE OF CHLORINE was discovered by Sir H. Davy in 1811, and, on account of its bright yellow-green colour, he called it euchlorine, from Greek words having that signification. It may be prepared by pouring a little sulphuric acid upon ten grains of chlorate of potash; the mixture should be stirred with a platinum knife,

and adjusted so that the salt and acid, when mixed, may constitute a yellow powder. This mixture being put into a bent glass tube, or very small retort, it must be heated by means of a water bath to 150° , and oxide of chlorine may then be collected in tubes over quicksilver.

This gas cannot be breathed: it dissolves in water in the quantity of eight or ten times the bulk of the water, which then acquires a lemon yellow colour. It is nearly the same as chlorine in weight. It is decomposed by gentle heat, and with a flash of light is enlarged in bulk, two volumes expanding into three, of which two are chlorine and one oxygen. By weight, it is composed of chlorine thirty-six, oxygen eight; making its atomic weight forty-four.

PEROXIDE OF CHLORINE was discovered by Sir H. Davy in 1815. It is obtained by reducing a quantity of chlorate of potash, not exceeding fifty grains, to powder, and then making it into a paste with strong sulphuric acid; the mixture being put into a glass retort, and submitted to the heat of water rather lower than the boiling point, a yellowish green gas is produced, of a richer colour than that of protoxide of chlorine. This gas has an aromatic odour, is rapidly absorbed by warm water, and destroys vegetable colours. When heated to 212° of Fahrenheit it explodes violently, forty measures expanding into sixty measures; forty of which are oxygen and

twenty chlorine. By weight, this gas is composed of thirty-six parts of chlorine, combined with thirty-two parts of oxygen; and, since equal bulks of oxygen and chlorine are to each other in weight as eight to thirty-six, it follows that the quantities entering into combination must be one proportion or atom of chlorine, with four proportions or atoms of oxygen. The atomic weight of the compound will, therefore, be sixty-eight.

CHLORIC ACID was accurately investigated by M. Gay Lussac, and may be obtained by passing a current of chlorine through a mixture of oxide of silver and water. The chloride of silver which is produced, being separated by filtration, and the excess of chlorine which the filtered liquor contains, being separated by heat, the chloric acid remains dissolved in the water. It is a sour and colourless liquid, which produces by combination compounds called chlorates. It consists of five proportions or atoms of oxygen and one of chlorine.

PERCHLORIC ACID is prepared by distilling oxychlorate of potash with its own weight of sulphuric acid. It cannot exist except in combination with water, and is but little known. It consists of seven proportions or atoms of oxygen and one of chlorine.

Before we proceed with the description of simple substances, and their compounds, it will be

necessary to describe, as briefly as possible, the improved principles upon which chemical compounds are now named.

When oxygen, chlorine, iodine, &c. combine together, or when they combine with other bodies without forming acids, the compounds are distinguished by the termination *ide*, as *oxide* of chlorine, *carbonic oxide*, *oxide* of iron, *chloride* of nitrogen, *iodide* of potassium. But, as the simple substances combine in different proportions with each other, it is requisite that these different combinations should be distinguished. When oxygen combines with a metal, in several proportions, the first syllables of the Greek ordinal numerals are prefixed. For example, oxygen combines with manganese in three proportions, the first will therefore be the *proto-oxide*; the second, the *deut-oxide*; and the third, the *trit-oxide*; but it is usual to call the oxide that contains the largest quantity of oxygen, the *per-oxide*. If oxygen combines with a body in two proportions only, as it does with copper, then the oxides will be called the *proto-oxide* and the *per-oxide*.

When the compounds have acid properties, the proportions of oxygen are marked by the syllables *ous* or *ic* added to the name of the base. Thus, the acid formed by the union of oxygen and nitrogen, which contains the smallest proportion of oxygen, is called *nitrous acid*; while that acid

which is formed by the union of a larger proportion of oxygen with nitrogen is called nitric acid.

When acids unite with oxides, forming secondary compounds, the acid containing the least oxygen gives the termination *ite*; that which has the largest proportion of oxygen gives the termination *ate*. Sulphurous acid and potash form sulphite of potash; sulphuric acid and potash constitute sulphate of potash. As the acids are capable of combining with the different oxides, their combinations must be distinguished. *Proto*-sulphate of iron is formed by the union of sulphuric acid and the *proto*-oxide of iron; *per*-sulphate of iron is formed by the union of sulphuric acid with the *per*-oxide of iron.

The compounds arising from the combination of electro-positive substances with each other, have the termination *uret*, as sulphuret of phosphorus, sulphuret of iron, phosphuret of carbon, carburet of iron. The syllable *bi* is prefixed to mark a double proportion of one of the constituent parts of a compound, as *bi*-sulphuret of phosphorus, which means that the compound contains twice as much sulphur as sulphuret of phosphorus.

IODINE was discovered in 1812, by M. Courtois, a manufacturer of saltpetre in Paris, while searching for the cause of the corrosion of his metallic vessels in his process of procuring soda

from the ashes of sea-weeds. It may be prepared by the following process: wash kelp with cold water, evaporate the liquid until a pellicle forms upon its surface; let it cool and crystallize; when the liquid ceases to deposit crystals evaporate it to dryness; mix the mass obtained with half its weight of sulphuric acid, and apply a gentle heat to the mixture in an alembic with a large capital attached to a globular receiver. Fumes of a beautiful violet colour fill the vessels, and soon condense into crystals of iodine. These crystals have a blackish, iron-gray colour, and a bright metallic lustre. Soapmakers' black ash may also be used for the purpose of procuring iodine. Dr. Ure recommends the residuum of soapmakers' ley, where kelp is the alkaline substance used. The liquid upon which he experimented was of a brown colour, and of an oily consistency. It converted vegetable blue to green, indicating free alkali: its boiling point he found to be 233° Fahrenheit. To obtain iodine, he heated the liquid to 230° , and then saturated it with sulphuric acid: the quantity of acid required was about one-fourth part of the bulk of the liquid, the acid being previously diluted with its own bulk of water. The mixture when cold yields a large quantity of saline crystals, chiefly sulphate of soda, a little sulphate of potash, and a few beautiful plates of hydriodate of soda, of an oblong rhomboidal shape. Sulphur is found

among the crystals. The liquid being filtered, he added 1000 grains of black oxide of manganese in powder to every twelve ounces of the liquid, apothecary's measure; he then put the mixture into a glass globe, or large matrass with a very wide neck, over which he inverted a glass globe, and then applied the heat of charcoal. He prevented the heat from affecting the receiver by putting a thin disc of wood with a round hole in its centre over the neck of the matrass. The iodine sublimes rapidly, and is condensed in the upper vessel, which is removed as soon as it becomes hot, and another put in its place; before this one is hot the other will be cold, and thus they may be substituted for one another as long as the vapour continues to rise. From the above-mentioned quantity Dr. Ure obtained from eighty to one hundred grains of pure iodine. It may be withdrawn from the globes by pouring in a little water, which dissolves but a very small portion. The crystals should be immediately dried upon blotting paper. The specific gravity of iodine is nearly 5. It smells like diluted chlorine, and has a very acrid taste. Starch is an exceedingly delicate test by which to detect the presence of iodine, producing with it in solution a deep blue colour. Its name was suggested by the colour of its vapour, and is derived from a Greek word, which signifies like a violet. A small quantity of it being inclosed in a tube or bulb, the heat of

the hand will be sufficient to convert some of it into vapour. By a heat, a little above that of boiling water, it melts, and assumes the state of dense violet-coloured fumes, which soon crystallize in plates and octohedrons. It changes vegetable colours to yellow, and stains the skin of the same colour. Although water is incapable of dissolving more than $\frac{1}{7000}$ part of its weight, it acquires the odour of the iodine, and a deep yellow colour: this solution is a test for starch, producing with it purple colour. It is dissolved more freely by ether and spirit of wine. Its combining proportion or weight is 124.

Oxygen and chlorine both combine with iodine; with the first it forms *iodic acid*; and with the second, *chloriodic acid*. The first of which consists of five volumes of oxygen and one of iodine.

The limits and design of this work will not permit enlargement upon chemical compounds that are comparatively unimportant. They must therefore be quickly passed over, to afford an opportunity of dwelling longer upon those that are of greater interest and utility.

BROMINE was discovered about four years since by M. Balard, of Montpellier. Its name is derived from a Greek word, signifying *rank odour*, this being a peculiar characteristic of the substance. It has so many near resemblances to chlorine and iodine, that it was at first supposed

to be some modification of one or other of these, but it is now accounted a simple substance.

It has been obtained chiefly from the residuum, or bittern, remaining after the crystallization of common salt from sea water : it has also been obtained from marine plants.

The process which M. Balard recommends for procuring bromine, is to pass a current of chlorine gas through bittern; chlorine having a strong attraction for hydrogen it occasions the decomposition of the hydro-bromic acid in the bittern, by which bromine is set free, giving an orange colour to the liquid. Sulphuric ether being then agitated with the liquid, it unites with the bromine, from which it receives a beautiful hyacinth red colour. The ethereal solution soon rises to the surface, and, being separated, it is agitated with caustic potash, by which hydrobromate of potash is formed, and obtained in crystals of a cubical shape by evaporation. Pure bromine may be obtained from these crystals by the agency of chlorine aided by heat. Bromine is now prepared with such facility as to enable it to be sold at a very cheap rate.

Bromine assumes the liquid form at common temperatures, it is of a dark red colour, and has a disagreeable smell, resembling that of chlorine; like the latter substance it destroys vegetable colours, and is a powerful poison. Its combining weight has not yet been determined with cer-

tainty, but is considered to be about seventy-five.

Bromic Acid, and

Hydro-bromic Acid are formed by the union of bromine and oxygen.

Chloride of Bromine is obtained by condensing the vapours which result when chlorine gas is passed through bromine. The latter substance also combines with iodine to form *Bromuret of Iodine*.

FLUORINE is a substance supposed to exist united with calcium in fluor spar, and with hydrogen in fluoric acid. It is now usually associated with the electro-negative substances although its separate existence is as yet hypothetical.

The SECOND CLASS of simple substances consists of HYDROGEN, NITROGEN, SULPHUR, PHOSPHORUS, CARBON, BORON.

HYDROGEN was known to early investigators in the science of chemistry, but it was first obtained pure, and accurately examined, by Mr. Cavendish, in 1776. Its name is derived from the Greek, and is intended to signify, as applied to hydrogen, *water former*.

Ex. 30. The best way of preparing it for the purposes of experiment, is to pour sulphuric acid, diluted with about eight times its bulk of water, upon small pieces of zinc, in a glass retort or a gas bottle, connecting the retort or bottle with a

gas holder, *c*, fig. 23, or with receivers on the shelf of the hydro-pneumatic trough, fig. 22. The gas comes over with great rapidity, without the aid of artificial heat. The theory of the process is thus explained. When the sulphuric acid is added to the zinc it acquires the power of decomposing water by attracting its oxygen, with which it combines to form oxide of zinc. The other component part of water, hydrogen, is set free, and, having very little attraction for water, it passes through and is received for experiment. The oxide of zinc formed by the oxygen of the water and the zinc, is dissolved by the acid to form sulphate of zinc. It is sometimes produced by passing steam over iron turnings, in a red hot gun barrel, or a bent tube prepared for the purpose.

This gas is the lightest of all substances capable of being weighed; one hundred cubical inches of it weigh only two grains and a quarter.

Ex. 31. It is so light, that if a burning taper be held over a bottle of it, a moment after the bottle is unstopped the gas will ascend, mix with the air, and, rendering it explosive, the mixture will take fire from the taper and explode, fig. 31.

Ex. 32. Its excessive lightness may also be shewn by attaching a pipe to a bladder filled with it, and inflating soap bubbles, fig. 32; the bubbles will ascend to the ceiling of the room

with great rapidity. The difference between it and common air may be shown, by blowing a few bubbles filled with common air; they will fall to the floor. These last experiments serve to illustrate the principles upon which balloons ascend, when filled with hydrogen or carburetted hydrogen gas.

Hydrogen has a slightly disagreeable smell, but no taste. It may be taken into the lungs; but a man cannot breathe it for more than a minute without danger. Small animals cannot live in it so long. When a person inspires this gas, it produces a very extraordinary change on the voice.

Ex. 33. It is inflammable: if a bottle of it be unstopped, and a burning taper be suddenly plunged in, it takes fire and burns, but the taper is put out.

Ex. 34. A jar, supplied with a stop-cock and small jet pipe, fig. 33, being filled with it, on the shelf of the hydro-pneumatic trough, when the jar is pressed down into the water, and the stop-cock opened, a candle being held near, the gas will take fire and burn with a flame that is not very luminous.

The combining proportion of hydrogen is 1, which being the smallest proportion by weight in which any bodies combine, it is made the standard with which to compare the combining proportions of other bodies.

Ex. 35. If a dry glass receiver, fig. 34, be held over the burning gas, the internal surface of it will immediately be coated with water: shewing that the hydrogen on burning combines with the oxygen of the air to produce water.

Ex. 36. If a small jar, *a*, fig. 35, be one-third filled with hydrogen, over water, and the remaining water be allowed to escape, air supplying its place, a candle held to the mouth of the jar will occasion the mixture to explode.

Ex. 37. If a tube about 18 inches in length, and at least half an inch diameter in the aperture, be held over the flame of hydrogen, various and pleasing sounds are produced; this property was thought peculiar to this gas, but Mr. Faraday has proved the contrary, similar sounds being produced by the flames of other gases. The cause of this effect is supposed to be successive explosions attending the burning of the gas in the tubes; a very simple apparatus serves for this experiment, fig. 36. Zinc, sulphuric acid, and water, being put into the bottle, the gas must be inflamed, and the apparatus will be ready.

A condensed mixture of oxygen and hydrogen in the proportion of the constituents of water, has been used for producing an intense heat. A current of the mixture being permitted to escape from a vessel where it exists in a state of condensation, it is inflamed, and the most refractory substances are melted with ease by the intense

heat of this flame. The instrument was first suggested by Mr. Brooks, and made by the ingenious manufacturer of philosophical instruments for the Royal Institution, Mr. Newman, of Regent Street. It is called the oxyhydrogen blow-pipe. Since its first introduction it has undergone a variety of alterations and improvements; but, notwithstanding, the use of it seemed to be attended with danger. A modification of it has been introduced by Mr. Gurney, to which this objection does not apply.

An elegant apparatus has been introduced for obtaining light by the sudden inflammation of hydrogen. A very fine stream of this gas is directed upon a small quantity of spongy platinum, which has the remarkable property of instantly becoming intensely hot, so as to inflame the hydrogen.

Hydrogen combines with oxygen in the proportion of two volumes of the former to one of the latter to constitute water. The atomic number or weight of water is 9.

Ex. 38. There are various processes by which the composition of water may be illustrated by experiment. The clearest of them shall be described. The jar, fig. 30, being filled with water, and set upon the shelf of the hydro-pneumatic trough, fig. 22, let two measures of hydrogen and one measure of oxygen be passed into it, then exhaust the thick glass vessel called Caven-

dish's apparatus, fig. 37, by the air-pump, close the stop-cocks, and, having put on a connecting piece, screw the apparatus to the jar, and open the stop-cocks, the vessel will be filled with the mixture; the stop-cocks must then be closed, the vessel unscrewed, and fixed upon its stand; a chain must be fastened upon one of the wires passing through the stopper of the apparatus, then charge a small jar with electricity, and, holding it by the outside, take the other end of the chain in the same hand, and pressing it close to the outside of the jar, apply the brass ball at the top of the jar, to the other wire in the stopper of Cavendish's apparatus, a communication will be made between the inside and the outside of the electrified jar, through the gas; the electrical fluid passing between the wires will explode it, a bright flash of light will be seen, and the inside of the apparatus will be moistened with water, formed by the union of the two gases in their proper proportions. To prove that the gases combine, leaving the space which they occupied void, open a communication between the vessel and water, and the water will rush in and fill it.

Ex. 39. The experiment may also be satisfactorily performed with the aid of an apparatus such as is represented at fig. 38. The cylindrical glass vessel, *a*, having been exhausted of common air, and filled with oxygen, it is attached to the receiver, *b*, which is filled with hydrogen.

The receiver being then pressed down into the water of the jar *c*, and the stop-cocks opened, the electric spark is applied, the hydrogen is inflamed, and, as it burns, the oxygen and hydrogen unite, and drops of water are seen to accumulate.

Ex. 40. It is easy to decompose water into its constituent parts; the best way, perhaps, is by voltaic electricity. Let the glasses *aa*, fig. 20. the tubes *cc*, and the syphon tube, *b*, be filled with pure water, the wires *ee*, being connected with the two ends of a voltaic battery, the water in the tubes will begin to be decomposed near the ends of the wires that pass through the tubes; the tube that is connected with the negative end of the battery will be filled with hydrogen, while the tube connected with the positively electrified end of the battery will be half filled with oxygen. Transfer these gases into a larger and stronger tube; apply a burning taper, or the electrical spark, and the mixture will explode with violence, proving it to be an explosive mixture of oxygen and hydrogen, of the same kind as was used for the purpose of forming water in a preceding experiment.

Ex. 41. The explosive nature of the constituents of water may be strikingly shewn, by filling a bladder with a mixture of two parts by bulk of hydrogen, and one part by bulk of oxygen; attach a pipe to the stop-cock of the bladder, as in a former

experiment, and having made a strong solution of soap, in an earthen-ware vessel, put the mouth of the pipe downwards into it, and inflate a number of soap bubbles on the surface of the solution, until the vessel is filled with them; then apply a lighted taper, and the gases will combine: the place which they occupied being suddenly left void, the air will rush in with such velocity as to occasion a very loud noise.

Ex. 42. Some bubbles filled with these gases may also, with the aid of the bladder and pipe, be blown in air; and if a lighted taper be applied to them, as they are ascending, they will explode with an expansive flash of flame.

Peroxide of hydrogen. Water may be made to combine with an excess of oxygen, by the agency of per-oxide of barium. Its specific gravity is then 1.45; it acts as a caustic upon the skin, and detonates with violence when dropped upon dry oxide of silver, and many other metals, in a finely divided state. This remarkable compound was discovered by M. Thenard. Per-oxide of hydrogen is composed of one proportion of hydrogen and two of oxygen; its number therefore is 17.

Ex. 43. HYDROGEN and CHLORINE being mixed in equal volumes, they combine on exposure to light, or on the application of the electric spark, to form *muriatic acid gas*; which is of the same bulk as the gases previous to their union.

The apparatus, fig. 37. is well adapted for this experiment. A communication being opened between the apparatus and water, after the explosion the water will rise into the vessel and absorb the gas. If a blue vegetable infusion be permitted to enter instead of water, it is instantly changed to red, by the acidity of the gas. Dr. Priestley first obtained this gas in a state of purity, but we are indebted to Sir H. Davy for a knowledge of its real nature.

This gas is incapable of being breathed, and it extinguishes burning bodies. It is eighteen times heavier than hydrogen; one hundred cubical inches of it weighing thirty-nine grains. When exposed, it occasions white fumes by combining with the moisture of the air. Several of the metals have the power of decomposing it, by attracting its chlorine; thus, potassium put into the gas in a retort when heat is applied, it combines with the chlorine of the acid, and sets the hydrogen free, which usually inflames. This gas being composed of one proportion of hydrogen 1, and one of chlorine 36, its equivalent number is 37.

In preparing muriatic acid, it is necessary to use a mercurial trough, on account of the strong attraction of the acid for water. It may be obtained easily by pouring sulphuric acid upon common salt.

This gas is so rapidly absorbed by water, that it is capable of condensing 480 times its bulk of the gas, by which it increases in weight nearly one quarter, and becomes liquid muriatic acid.

Ex. 44. The process for making this acid is as follows: put into a retort *a*, fig. 39. common salt and sulphuric acid in the proportions of thirty-two parts salt, and twenty-two of acid; but the acid must be diluted with one third its weight of water; the retort must be connected with the receiver *b*, and made air tight, by luting; there must be double the quantity of water in this receiver that was used for diluting the sulphuric acid; the receiver must be connected with the other vessels *c*, *d*, and *e*, by means of the tubes which are fitted by grinding, or by being passed through corks which are made air tight by a mixture of drying oil and pipe-clay. The sand-bath affords the best means of applying heat. The three necked bottles, *c*, *d*, and *e*, must be about half filled with water, into which the safety tubes *f*, *f*, *f*, must dip a little way. When distillation of this kind is going on, the receiver *b* is intended to collect any condensible product, and the gas is made to pass through water in the bottles under a slight pressure, that the water may be saturated with it. The safety tubes prevent any accident which might be occasioned by absorption; as in case of a partial void being produced

in that way, the air can get in through the tubes. This is one form of the apparatus invented by Woulfe.

The nature of the process is thus explained. Common salt being a compound of chlorine and sodium ; when sulphuric acid diluted with water, is poured upon it, the water is decomposed, its oxygen combines with the sodium, forming soda ; which unites with the sulphuric acid, constituting sulphate of soda ; while the hydrogen of the water combines with the chlorine, to produce muriatic acid.

Sir H. Davy has given the following table indicating the quantity of real acid contained in a hundred parts of liquid muriatic acid, of different specific gravities, at the temperature of 45° Fahrenheit, the Barometer being at 30 inches.

Specific gravity.	100 grains contain of muriatic acid gas.	Specific gravity.	100 grains contain of muriatic acid gas.
1.21	42.43	1.10	20.20
1.20	40.80	1.09	18.18
1.19	38.38	1.08	16.16
1.18	36.36	1.07	14.14
1.17	34.34	1.06	12.12
1.16	32.32	1.05	10.10
1.15	30.03	1.04	8.08
1.14	28.28	1.03	6.06
1.13	26.26	1.02	4.04
1.12	24.24	1.01	2.02
1.11	22.30		

Mr. Faraday succeeded in liquifying the pure dry acid under a pressure calculated at forty-five atmospheres.

Hydrogen unites with *iodine* to form *hydriodic acid*. It may be obtained by submitting phosphorus to the action of moist iodine. It must be received over mercury, and ought to be removed as quickly as possible, as it is decomposed by the mercury with which it is in contact. The apparatus best adapted for this experiment, is a bent tube, or a very small retort; the iodine must be introduced into the bulb of the retort, and afterwards the phosphorus. The gas is rapidly produced, and when it ceases, an additional portion may be obtained by applying the heat of a lamp.

This acid has an odour like that of muriatic acid; it is destitute of colour, tastes very sour, and is exceedingly heavy; compared with hydrogen, it is as 59.3 to 1. One hundred cubical inches of it weigh 133.6 grains. Water absorbs it very quickly; but liquid hydriodic acid may be better obtained by passing sulphuretted hydrogen through a mixture of iodine and water; sulphur will be deposited, and the liquid, when heated and filtered, will contain a solution of pure hydriodic acid, which may be concentrated by evaporation.

One volume of this gas, being submitted to the action of mercury, the iodine is absorbed, and the hydrogen, consisting of half the original volume, remains; proving that this gas is composed of equal volumes of vapour of iodine and hydrogen. Its equivalent number is 125.

Chlorine combines with its hydrogen, forming muriatic acid, while the vapour of iodine is rendered sensible. The action between these gases is so violent that they often take fire as soon as they come into contact.

NITROGEN or AZOTE constitutes four-fifths in the composition of common air, from which it may be obtained after the oxygen is withdrawn by the combustion of hydrogen or phosphorus, as already mentioned in describing eudiometry. Or it may be formed directly by submitting animal matter, such as muscular fibre, or glue, to the action of nitric acid, diluted with ten times its weight of water in a glass retort. This gas was first discovered by Dr. Rutherford, in 1772. It is destitute of taste and smell, and is incapable of supporting animal life or combustion; one hundred cubical inches of it weigh 29.65 grains, its specific gravity being as thirteen to one, compared with hydrogen. Nitrogen forms four very important compounds by its union with oxygen in five different proportions. Its atomic number is 14.

Protoxide of nitrogen, or nitrous oxide;

Deutoxide of nitrogen, or nitric oxide;

Hyponitrous acid;

Nitrous acid; and

Nitric acid.

Dr. Priestley discovered nitrous oxide gas in 1772, but its nature was first accurately investigated by Sir H. Davy.

Nitrate of ammonia being exposed to a heat of 420° in a glass retort, over an argand lamp, nitrous oxide gas will be copiously evolved, and may be received over warm water; one hundred cubical inches of it weighing 46.516 grains.

According to the atomic theory, the compound of nitrogen and oxygen, that contains the least proportion of the latter, is considered as a compound of one atom of nitrogen and one of oxygen, and its atomic weight is 22.

Water, deprived of its atmospheric air, is capable of absorbing its own bulk of this gas, but evolves it again when heated. It has a faint and rather agreeable odour, and a sweet taste. A taper burns brilliantly in it, with a bluish-coloured halo around the flame. Burning phosphorus plunged into it burns with greater brilliancy; but if it is not ignited before it is introduced, it may be melted and sublimed without taking fire.

This gas may be breathed, but it is not fitted to support life. Sir H. Davy discovered that it produces a species of intoxication, when breathed for a short time. Different persons are differently affected by it, but in general, the sensations seem to be pleasurable; and a strong tendency to muscular action is also experienced. Those who are most affected by the gas are not sensible of their own actions, any more than persons in an advanced state of intoxication.

As the novelty of the effects produced by this

gas passes away, the rage for inhaling it seems to decline. There are individuals who think that exhibitions afforded by persons inhaling this gas are not of the most interesting order. It does not seem desirable, to see grave and respectable persons assuming, before public companies, the character of inebriated men. The effects produced are sometimes so violent, that the author of this work has seen individuals, under the influence of the gas, much more like raving maniacs than intoxicated persons, biting the tube, from which they inhaled the gas, with such force as to render it extremely difficult to remove it. It is affirmed, that this kind of excitement is not followed by depression; but instances have occurred of great languor and debility being produced by excessive excitement in this way.

Ex. 45. Nitrous oxide is readily analyzed by the combustion of hydrogen, carbon, or phosphorous. One volume of nitrous oxide being mixed with one volume of hydrogen in a detonating tube, fig. 40. after the application of the electrical spark, nothing will remain but one volume of nitrogen; the volume of hydrogen being converted into water, must have combined with half a volume of oxygen, which was taken from the nitrous oxide, leaving one volume of nitrogen: nitrous oxide is composed therefore of two volumes of nitrogen and one of oxygen, condensed by chemical union into two volumes. Nitrous

oxide has been converted into a colourless liquid under a pressure of about fifty-two atmospheres.

Deutoxide of nitrogen, nitric oxide, or nitrous gas, was also first described by Dr. Priestley, in 1772. To obtain it, pour some nitric acid, diluted with about four times its bulk of water, into a gas bottle, or a glass retort containing copper turnings or filings, and heat gently; red fumes are produced, and the gas may be received over water, or better over mercury. Water absorbs one twentieth part only of its volume of this gas; but it is absorbed in large quantity by solution of proto-muriate or proto-sulphate of iron, forming a dark coloured liquid, which is the eudiometric liquid used by Sir H. Davy.

When a vessel containing this gas is exposed to the air, red fumes arise from it, occasioned by the absorption of oxygen, and consequent formation of nitrous acid. Oxygen would be absorbed in the lungs of an animal breathing this gas; nitrous acid would be formed, and instant death would ensue.

Burning phosphorus plunged into this gas, continues to burn with encreased splendour; but the flame of a taper is extinguished, as is that of sulphur. Homberg's pyrophorous thrown into it, burns spontaneously.

Its weight compared with hydrogen is as fourteen to one; 31.77 grains being the weight of one hundred cubical inches. Its atomic number is 30,

Some of the metals have the property of abstracting oxygen from this compound, as arsenic, zinc, and potassium, when aided by considerable heat; by which it is ascertained to be composed of equal volumes of nitrogen and oxygen. Nitrous gas is converted into nitrous acid, by chlorine, when water is present; the water being decomposed, supplies oxygen to the nitrous gas, by uniting with which, it becomes nitrous acid; while the chlorine combines with the hydrogen of the water to form muriatic acid gas.

Hyponitrous acid is formed when oxygen gas is mixed with an excess of deutoxide of nitrogen in a glass tube over mercury, a strong solution of pure potash having been previously put into the tube. The oxygen and the deutoxide combine in the proportion of one hundred measures of the former with four hundred measures of the latter, the acid formed unites with the potash. This acid being composed of one proportion of nitrogen and three proportions of oxygen, its atomic number is 38.

Nitrous acid gas results when two volumes of nitrous gas are mixed with one volume of oxygen in exhausted vessels; these gases are condensed into about half their volume of nitrous acid gas, of a deep orange colour. Both quicksilver and water absorb this gas; hence the necessity of using exhausted vessels for experiments upon it. When the mixture constituting nitrous acid, is

made over water, the whole will be absorbed, if the gases are pure, producing a green acid liquid, but any uncombined oxygen or nitric oxide will remain. Burning sulphur is extinguished when plunged into this gas, but a taper burns in it, as do phosphorus and charcoal.

Pure nitrous acid may be obtained by heating nitrate of lead in a glass retort, the acid comes over in the form of a yellow coloured liquid, which is so volatile, that it boils at the temperature of 82° . Its specific gravity compared with hydrogen, is as 28.6 to 1, and the weight of one hundred cubical inches is 64.5 grains. Its atomic number is 46.

Nitric acid was first accurately examined and its composition proved by Mr. Cavendish, in 1785.

Ex. 46. It may be readily obtained by cautiously adding two parts of strong sulphuric acid to three parts of pure nitrate of potash, in a glass retort; having previously joined the retort, by means of an adapter, to a large tubulated receiver; the joints being secured by the drying oil and pipe-clay lute, a communication must be established between the receiver and another vessel containing water; the most convenient heat to apply will be that of an argand lamp. An apparatus adapted to this experiment upon a small scale, is represented by fig. 41: *a, a*, two brass stands with sliding rings, for supporting the the lamp *b*, a tubulated retort, *c*, which may have a

stopper instead of the safety tube, *d*, an adapter, *e*, a receiver, *f*, a bent tube, *g*, and an additional receiver, *h*, containing some water. The tube is not luted into the neck of the last receiver. If it should seem desirable another tube may easily be adapted to the wide neck of the receiver, which must then be closed, for the purpose of conveying any gaseous products that may be produced into proper receivers.

For the distillation of nitric acid upon a large scale, a thick cast iron retort is used, which has an earthenware head adapted to it, and the receivers are also of earthenware: 112 pounds of nitrate of potash and 56 pounds of sulphuric acid, produce from 50 to 52 pounds of nitric acid.

Liquid nitric acid should be colourless and of the specific gravity 1.5; it is excessively sour and corrosive. The nitric acid of commerce is generally impure, being contaminated with muriatic and sulphuric acids coloured with nitrous acid gas, and diluted with water; it is known in that state, by the name of *aqua-fortis*.

The uses to which this acid is applied in the arts are very numerous indeed. Some of them may be mentioned. It is used by engravers for etching on copper; by dyers to form a solution of tin, which is used as a mordant for some of the finest dyes; it is useful in metallurgy and assaying, and in various chemical processes, on account of the facility with which it parts with

its oxygen, and dissolves metals ; as a tonic in medicine, and in the state of vapour to destroy contagion.

The common aqua-fortis of the shops is usually prepared by mixing nitrate of potash with its own weight of sulphate of iron, and half its weight of the same sulphate calcined, and distilling the mixture. Or, it may be prepared by mixing nitre with double its weight of dry powdered clay, and distilling in a reverberatory furnace. The double aqua-fortis of the shops, is about half the strength of nitric acid, and the single aqua-fortis is about half the strength of the double.

A mixture of nitric and muriatic acids has the property of dissolving gold and platinum, which neither of the acids can do separately. When these acids are mixed together, they undergo change ; the hydrogen of the muriatic acid combines with some of the oxygen of the nitric acid to form water, and chlorine and nitrous acid remain. It is the chlorine that combines with the gold and platinum. This acid being composed of one proportion of nitrogen 14, with 5 proportions of oxygen, five times $8 = 40$, the atomic number is 54.

Chloride of nitrogen. A solution of muriate or nitrate of ammonia, consisting of one part of the salt, and twelve parts water, being poured into a glass bason, invert in it a tall jar of chlorine, the gas will gradually be absorbed, and

small globules of a yellowish oily looking substance begin to collect. The temperature of the solution ought to be from 60 to 70°. These globules are violently explosive, when brought into contact with a variety of substances. A small syringe, made of glass tube, drawn to a bent point, with a small aperture, is used for transferring the globules. One of these not larger than a mustard seed, being drawn into the syringe, and transferred to a clean earthenware bason, partly filled with water, fasten a small piece of phosphorus to the end of a stick, and make it touch the globule, it will instantly explode, disperse the water, and break the bason. The following substances have all been found capable of causing it to explode. Phosphorus, phosphoret of lime, caoutchouc, myrrh, palm-oil, whale-oil, linseed and olive oils, oil of turpentine, naptha, liquid ammonia, phosphuretted hydrogen, and nitric oxide.

This curious compound is composed of one volume nitrogen, and four volumes chlorine. Its atomic number is 158.

Iodide of Nitrogen. Nitrogen may be made to combine with *iodine*, by pouring a solution of ammonia over a small quantity of the latter substance ; one of the products is a brown powder, which detonates on being slightly touched. It must be placed upon blotting paper in small parcels, and be allowed to dry by exposure to air.

Ammonia. Nitrogen unites with *hydrogen* to form *ammonia*, an exceedingly important compound, which was first obtained pure by Dr. Priestley.

Ex. 47. It is usually prepared for experiment, by heating two parts of quicklime and one part of muriate of ammonia, in powder, in a glass retort, or in an earthenware bottle furnished with a glass tube; this answers equally well, and is not liable to break, like the glass retort. The gas must be received over mercury, as water absorbs it very rapidly. This gas is very acrid and pungent, but when diluted with common air, it is agreeably stimulant. It first enlarges the flame of a taper, and then extinguishes it. It has the characteristic properties of alkalies in a high degree; neutralizing acids, and converting vegetable blues to green, and yellows to red. Water at the temperature of 50° absorbs 670 times its bulk of this gas, which may be obtained again unaltered by heating the water. Ammonia is most extensively useful in its state of combination with water, in which state it is called liquid ammonia. This liquid may be prepared either by saturating water with the gas, or it may be distilled in combination with water. For the first process the Woolfe's apparatus, fig. 39, is well adapted. The proportions of lime and muriate of ammonia have already been mentioned, and an earthenware bottle or retort has been re-

commended for holding them, instead of a glass retort. When gas ceases to be evolved in this process, Dr. Ure recommends the addition of a little hot water, which will renew the evolution, and ensure complete decomposition of the salt.

The process for distilling the gas in combination with water, recommended by Mr. R. Phillips is as follows : to nine ounces of well burned lime, add half a pint of water, and let it remain in a close vessel for an hour, then add twelve ounces of powdered muriate of ammonia, and three pints and a half of boiling water. When the mixture has cooled, pour off the clear solution, and distil from a retort twenty fluid ounces. The specific gravity of this solution will be 0.954, which is as strong as is usually required, and stronger than it is often sold in the shops.

Since the specific gravity of water is reduced in proportion to the quantity of this gas with which it combines, the strength of the solution will be indicated by the specific gravity ; tables have accordingly been calculated upon this principle ; the following is from the Elements of Chemical Philosophy, by Sir H. Davy. The first column expresses the specific gravity, and the second column expresses the number of parts of pure ammonia in one hundred parts of the specific gravity opposite ; a third column might be added to shew the quantity of water, as the difference between each number in the last

column, and 100 would express the quantity of water in the compound.

100 parts of specific gravity	Yield of ammonia
8750	32.5
8875	29.25
9000	26.00
9054	25.37
9166	22.07
9255	19.54
9326	17.52
9385	15.88
9435	14.53
9476	13.46
9513	12.40
9545	11.56
9573	10.82
9597	10.17
9619	9.60
9692	9.50

This liquid requires to be preserved in well stopped bottles, to prevent the gas from escaping.

Dr. Henry discovered that ammoniacal gas may be analyzed by applying the electric spark, to a mixture of it with oxygen, which explodes, and is converted into water and nitrogen.

Berthollet decomposed this gas, by making it pass slowly through a small ignited porcelain tube. 100 cubical inches treated in this way were converted into 200 cubical inches of the constituent gases, 50 parts of which were found to be nitrogen, and 150 hydrogen. So that, ammoniacal gas must be composed of one volume of nitrogen, and three volumes hydrogen, which makes its atomic number 17.

Phenomena which have excited a great deal of attention, but which are not yet satisfactorily explained, take place when voltaic wires are applied to a globule of quicksilver, in contact with liquid ammonia. A small globule of mercury may be put into a hollow, made in a piece of sal ammoniac, with a little liquid ammonia, the negative wire proceeding from the voltaic combination must touch the mercury, and the positive wire must be in contact with the water of ammonia; a circulating film immediately covers the globule, a white smoke rises from it, its volume enlarges, and it shoots out ramifications of a soft semi-solid amalgam over the salt. When the communication between the two ends of the voltaic combination is suspended, these fibres retract towards the central mass, which soon, by the constant formation of white saline films, resumes its original globular appearance. When a small globule of mercury is employed, the enlargement of volume will sometimes amount to ten times the original size. A portion of potassium being used instead of quicksilver, a similar appearance will be produced.

The salts that are formed by the union of ammonia with the acids, are mostly soluble in water, evolve an ammoniacal odour, when mixed with potash or lime, and are decomposed and dissipated when sufficient heat is applied.

Chlorate of ammonia may be obtained by sub-

mitting solutions of chlorate of lime and carbonate of ammonia to each other; the lime of the chlorate of lime will attract carbonic acid from the carbonate of ammonia, while the chloric acid will combine with the ammonia, to form chlorate of ammonia, which may be obtained by evaporation. Or it may be obtained by saturating chloric acid with carbonate of ammonia. The acicular crystals produced are very soluble, both in water and alcohol; they are decomposed by moderate heat, and detonate when thrown upon hot coals.

When *ammonia* and *chlorine* in the gaseous form are brought into contact, if they are perfectly dry, and in the proportions of fifteen parts chlorine and forty ammonia, the latter is decomposed with almost explosive energy, producing heat and flame; muriate of ammonia is formed, and nitrogen set free.

This experiment is most safely performed by filling wide necked bottles having flat rims, fitted to each other by grinding, with the proper proportions of gas; invert that which contains the chlorine over the other, holding a bottle in each hand.

Muriate of ammonia or *sal ammoniac* is most readily formed by mixing equal volumes of muriatic acid gas and ammoniacal gas. Bottles, such as are recommended for the last experiment, answer well for this.

Sal ammoniac is an article of great importance in the arts. The dyer uses it in the preparation of nitrate of tin to moderate the action of nitric acid, and also to produce modifications of some colours. It is used in the processes of tinning and soldering, to protect the surfaces to be tinned or soldered from oxidation. It is used in the preparations of some medicines; it is useful in producing artificial cold; in analyzing metallic combinations, and in the processes for preparing liquid ammonia and smelling salts. The workers in metals at Birmingham are said to consume at least twenty tons of this salt annually. This valuable article was originally and for a length of time, exclusively manufactured in Egypt, from soot, obtained by burning the dung of camels and other similar substances; twenty-six pounds of soot, yielding about six pounds of sal ammoniac.

It is now prepared in France, and in this country by burning bones, horns, hoofs, parings of hides, and other animal matters in one retort, while heat being applied to a mixture of sulphuric acid and common salt, in another, the fumes are made to meet in an apartment partly lined with lead and having water on the floor, portions combine and form solid incrustations of muriate of ammonia on the walls, while other portions combine with the water, forming a solution of muriate of ammonia, from which the salt may be obtained by evaporation.

Muriate of ammonia is found native in volcanic districts. The ancients, according to Pliny, gave the name ammoniac to this salt on account of it having been found near the temple of Jupiter Ammon, in Africa.

Hydriodate of ammonia may be produced by mingling equal bulks of hydriodic and ammoniacal gases, or by adding carbonate of ammonia to liquid hydriodic acid, until the acid is saturated.

Nitrate of ammonia, the salt from which nitrous oxide is usually prepared, may be obtained by saturating dilute nitric acid with carbonate of ammonia, or by the direct union.

SULPHUR occurs native in many parts of the world. It is found in the largest quantities in volcanic districts ; it is also obtained by distillation from the metallic ores called Pyrites. When crystallized, its crystals are of an octahedral form, sometimes transparent. It is a nonconductor of electricity. It melts at about 220° , and begins to volatilize even before it reaches that temperature. At 300° it thickens ; in which state, if it be poured into water, it continues ductile, and assumes a red colour. It is prepared in that way for receiving impressions of medals. Being heated to about 420° it is then poured into water, and becomes a ductile mass well adapted to the purpose. Heated to 600° it assumes the state of vapour and is sublimed.

The roll sulphur of commerce is in this coun-

try obtained chiefly from sulphuret of copper, which is roasted for the purpose of expelling the sulphur; it is condensed in a compartment of the flue prepared for it, from whence it is taken to be purified, by remelting, and is then cast into the form in which it is most commonly found in the shops.

To try the purity of sulphur it may be heated upon a piece of platinum foil; it will entirely evaporate if it be perfectly pure. Its combining proportion is 16.

The combinations of sulphur with oxygen are all of an acid nature; there are four of them, hypo-sulphurous acid, sulphurous acid, hypo-sulphuric acid, and sulphuric acid.

Hypo-sulphurous acid is composed of two proportions of sulphur and one of oxygen; its compounds are called hypo-sulphites. Its atomic number is 40.

Sulphurous acid consists of one proportion of sulphur and two of oxygen. When sulphur is burned in oxygen gas, sulphurous acid gas is the result. As water absorbs about thirty times its bulk of this gas, it must be collected over mercury. In this experiment one hundred cubical inches of gas, weighing 33.75 grains, combine with the same weight of sulphur. This gas may be condensed into a liquid under a pressure of two and a half atmospheres. On distilling it from a mixture of sulphuric acid and mercury, it

may be obtained in the liquid state by keeping the receiving vessels very cold. This gas is condensed into a liquid under less pressure than any other.

This gas destroys the colours of some animal and vegetable substances, as silk, cotton, wool, and straw, hence its use in bleaching such substances. It has an astringent taste, and a suffocating smell; it is incapable of supporting life or combustion. One hundred cubical inches of it weigh 67.5 grains. Its atomic weight is 32.

Equal volumes of sulphurous acid gas and ammoniacal gas, form *sulphite of ammonia*.

Sulphuric acid, when pure, is destitute of colour and of smell, and it has the appearance of oil; it is strongly acid, a single drop being capable of reddening a large quantity of water, tinged with vegetable blue. It is a powerful caustic, and when taken into the stomach, occasions dreadful agonies, convulsions, and death. Its atomic number is 40.

Sulphuric acid is of great use in the arts and manufactures: a few of its most prominent applications may be mentioned. It is essential to gilders, brass-workers, and tinned iron plate makers; it is necessary in the manufacture of some of the other acids; in the processes of bleaching and dyeing; and in chemical processes and investigations.

This acid is now prepared upon a very exten-

sive scale in this and other countries. Large rooms, lined with lead, are used for this purpose, having upon their floors a shallow stratum of water. A mixture of eight parts of sulphur with one of nitre, being set on fire, is introduced into the leaden chamber, the vapours produced fill the apartment, and gradually condense in the water. The materials to be burned are best supported upon an iron plate, with an upright border; the plate is supported, at the height of about a foot from the floor, upon a small furnace, in which a fire is made when the ingredients are to be inflamed. A pane of glass, adapted to the trap door of the chamber, enables to see when the combustion is finished; the trap-door is then opened, the residuary sulphate of potash is withdrawn, and a new supply of sulphur and nitre introduced. The air in the apartment being renewed by opening doors in different sides; the doors are again closed, and the sulphur is again inflamed. Thus successive mixtures are burned until the water on the floor attains a specific gravity of about 1.390, the acid is then withdrawn by stop-cocks, and evaporated in vessels of lead, and then of glass, until it arrives at the specific gravity of 1.8485, which is the utmost concentration to be desired.

One hundred parts of nitre judiciously managed, will produce, with the requisite quantity of sulphur, 2000 parts of concentrated sulphuric acid. This quantity of acid contains 1200 parts of

oxygen, while the quantity of nitre used, contained only thirty-nine and a half of oxygen, which is less than one-thirtieth part of the whole. But after the combustion of the sulphur, the nitre is converted into sulphate and bisulphate of potash, which contain nearly as much oxygen as the nitre originally contained. From whence then is the oxygen derived which enters into the sulphuric acid? The question has been thus answered by M. M. Clement and Desormes. The burning sulphur, or sulphurous acid, taking from the nitre a portion of its oxygen, forms sulphuric acid, which unites with the potash, and displaces a little nitrous and nitric acids in vapour. These vapours are decomposed by the sulphurous acid, into nitrous gas. This gas, naturally little denser than air, and now expanded by heat, suddenly rises to the roof of the chamber, and might be expected to escape at the aperture there, which manufacturers are always obliged to leave open, otherwise they find the acidification will not proceed. But the instant that nitrous gas comes in contact with atmospheric oxygen, nitrous acid vapour is formed, which being a very heavy aëriform body, immediately precipitates on the sulphurous flame, and converts it into sulphuric acid; while itself, resuming the state of nitrous gas, reascends for a new charge of oxygen, again to descend, and transfer it to the flaming sulphur. Thus we see, says Dr. Ure, that a small volume of nitrous

vapour, by its alternate metamorphoses into the states of oxide and acid, and its consequent interchanges, may be capable of acidifying a great quantity of sulphur.

But Sir H. Davy found that nitrous gas had no action on sulphurous gas to convert it into sulphuric acid, unless water be present. With a small proportion of water, four volumes of sulphurous acid gas, and three of nitrous gas, are condensed into a crystalline solid, which is instantly decomposed by *abundance* of water; oil of vitriol is formed, and nitrous gas given off, which, with contact of air, becomes nitrous acid gas, as above described.

Alembics of platinum, placed within pots of cast iron, have recently been introduced instead of glass, for the concentration of sulphuric acid; they are found to quicken the process and save fuel.

Sulphuric acid produced by the process described, is usually sufficiently pure for most purposes in the arts; but as it is generally more or less contaminated with lime, potash, and lead, it requires to be distilled to fit it for the nicer purposes of chemistry. Sulphuric acid of specific gravity 1.85 distils unaltered at 540° Fahrenheit. In distilling this acid great care is necessary, for when it boils, vapour is produced with almost explosive violence, endangering the vessels employed. It may, however, be made to boil gently,

and without danger, by using a vessel capable of holding a much larger quantity of acid than is put into it, and by immersing some slips of platinum in the liquid.

Mr. Hill, of Bromley, has a patent for producing sulphuric acid without nitre, by heating bruised iron pyrites in cylinders, communicating with a leaden chamber, containing water. The sulphur of the pyrites, on burning, is said to assume the state of sulphuric acid. Sulphuric acid when sufficiently concentrated is put into large glass bottles, called carboys, and packed in baskets for sale.

The impurities contained in the acid of commerce, chiefly sulphate of lead, may be got rid of in some measure, by diluting with water; a white powder is deposited.

The strength of sulphuric acid is ascertained by trying its specific gravity, or by its power of saturating alkalies, which is the best method. It has been found that one hundred grains of dry sub-carbonate of soda, neutralize ninety-two grains of pure liquid sulphuric acid; or that one hundred grains of the acid require 108, or 108.5, of the sub-carbonate for saturation.

Tables have been constructed by Dalton, Parkes, Ure, and others, shewing the quantity of acid of commerce in diluted sulphuric acid, of different densities. As a right understanding of this subject is of great importance to all who use

sulphuric acid, the table of Dr. Ure is here inserted.

TABLE of the quantity of oil of vitriol or dry sulphuric acid in one hundred parts of dilute acids, at different densities.

Liquid.	Specific Gravity.	Dry.
100	1.8485	81.54
99	1.8475	80.72
98	1.8460	79.90
97	1.8439	79.09
96	1.8410	78.28
95	1.8376	77.46
94	1.8336	76.65
93	1.8290	75.83
92	1.8233	75.02
91	1.8179	74.20
90	1.8115	73.39
89	1.8043	72.57
88	1.7962	71.75
87	1.7870	70.94
86	1.7774	70.12
85	1.7673	69.31
84	1.7570	68.49
83	1.7465	67.68
82	1.7360	66.86
81	1.7245	66.05
80	1.7120	65.23
79	1.6993	64.42
78	1.6870	63.60
77	1.6750	62.78
76	1.6630	61.97
75	1.6520	61.15
74	1.6415	60.34
73	1.6321	59.52
72	1.6204	58.71
71	1.6090	57.89
70	1.5975	57.08
69	1.5868	56.26
68	1.5760	55.46
67	1.5648	54.63
66	1.5503	53.82
65	1.5390	53.00
64	1.5280	52.18
63	1.5170	51.37
62	1.5066	50.55

Liquid.	Specific Gravity.	Dry.
61	1.4960	49.74
60	1.4860	48.92
59	1.4760	48.11
58	1.4660	47.29
57	1.4560	46.48
56	1.4460	45.66
55	1.4360	44.85
54	1.4265	44.03
53	1.4170	43.22
52	1.4073	42.40
51	1.3977	41.58
50	1.3884	40.77
49	1.3788	39.95
48	1.3697	39.14
47	1.3612	38.32
46	1.3530	37.51
45	1.3440	36.69
44	1.3345	35.88
43	1.3255	35.06
42	1.3165	34.25
41	1.3080	33.43
40	1.2999	32.61
39	1.2913	31.80
38	1.2826	30.98
37	1.2740	30.17
36	1.2654	29.35
35	1.2572	28.54
34	1.2490	27.72
33	1.2409	26.91
32	1.2334	26.09
31	1.2260	25.28
30	1.2184	24.46
29	1.2108	23.65
28	1.2032	22.83
27	1.1956	22.01
26	1.1876	21.20
25	1.1792	20.38
24	1.1706	19.57
23	1.1626	18.75
22	1.1549	17.94
21	1.1480	17.12
20	1.1410	16.31
19	1.1330	15.49
18	1.1246	14.68
17	1.1165	13.86
16	1.1090	13.05
15	1.1019	12.23
14	1.0953	11.41

Liquid.	Specific Gravity.	Dry.
13	1.0887	10.60
12	1.0809	9.78
11	1.0743	8.97
10	1.0682	8.15
9	1.0614	7.34
8	1.0544	6.52
7	1.0477	5.71
6	1.0405	4.89
5	1.0336	4.08
4	1.0268	3.26
3	1.0206	2.446
2	1.0140	1.63
1	1.0074	0.8154

Ex. 48. The easiest and readiest method of trying the specific gravity of sulphuric acid, is to use a specific gravity bottle, as it is called. The bottle should hold some even quantity of pure water, say 1000 grains. In order to try the specific gravity of sulphuric acid with the aid of such a bottle, first balance it in a delicate pair of scales, then fill it with the acid and weigh it: if the acid is of the greatest strength, its weight, exclusive of the balance, will be about 1848 grains; the bottle will weigh less in proportion as the acid is weaker, and the difference may easily be estimated by reference to the foregoing table, for it will be sufficiently near the truth for common purposes, to consider the acid weighed, of the same specific gravity as that in the middle column of the table, the first four figures of which correspond with the weight of the acid in grains. Thus, if the weight of the quantity of

acid that fills the bottle should be 1829 grains, its specific gravity may be considered the same as that which is expressed in the eighth line of the table from the beginning.

Attention must be paid to the temperature of the acid, when trying its specific gravity, as a high temperature will diminish the density, and a low temperature will increase it.

When one part of water is suddenly mixed with four parts of concentrated sulphuric acid, the heat of the mixture will be raised to 300° Fahrenheit and upwards, because the capacity for heat of sulphuric acid and water when mingled, is less than that of the water and the acid when separate; condensation ensues also when these liquids are mixed, and it is found that when they are mixed in such proportions as to occasion the greatest degree of condensation, the greatest increase of temperature is also produced.

Ex. 49. The rise of temperature produced in this way is strikingly shewn by mixing small quantities of acid and water, in a wine glass; a test tube containing some ether being immersed in the mixture, the ether boils violently.

Inflammable substances decompose sulphuric acid at the temperature of the atmosphere, darkening its colour; a very small piece of sugar, wood, cork, or other vegetable substances will produce this effect; so that any such substances should be carefully prevented from coming into contact with the acid.

By passing sulphuric acid through a red hot platinum tube, it is decomposed, and the substances produced are, sulphurous acid, oxygen, and water. Forty is the atomic weight of this acid, since it is composed of one proportion sulphur 16, and three of oxygen $24=40$.

Hypo-sulphuric acid is produced when a current of sulphurous acid gas is made to pass through water, which has fine powder of peroxide of manganese diffused through it. The sulphurous acid obtaining oxygen from this latter substance, is partly changed into sulphuric and partly into hypo-sulphuric acid. Solution of pure barytes being added to the liquid, a little in excess, protoxide of manganese is precipitated, and insoluble sulphate of barytes is formed with the sulphuric, and soluble hypo-sulphate with the hypo-sulphuric acid. The quantity of sulphuric acid used should be just sufficient to decompose the hypo-sulphate of barytes, and hypo-sulphuric acid remains in solution. It is composed of two proportions of sulphur, and five proportions of oxygen; its atomic number is therefore seventy-two.

Sulphate of ammonia is formed by submitting carbonate of ammonia to the action of dilute sulphuric acid, until it is saturated, or it may be obtained by the decomposition of muriate of ammonia, by sulphuric acid.

Chloride of Sulphur is produced by heating

sulphur in chlorine, ten grains of sulphur are capable of combining with thirty cubical inches of chlorine, forming a greenish yellow liquid, which is chloride of sulphur.

Sulphur unites with *iodine* to produce a black crystallizable substance.

Sulphuretted hydrogen gas may be prepared in several different ways, the following are some of the best. Pour dilute sulphuric acid upon sulphuret of iron, or heat sulphuret of antimony in coarse powder with muriatic acid; the gas will be evolved, and may be received over water. Dr. Henry recommends acting upon sulphuret of potash, prepared by boiling flowers of sulphur with potash, free from carbonic acid.

The smell of this gas is extremely offensive, resembling rotten eggs; it is inflammable, it tarnishes polished metals, and blackens paint of which white lead is the basis. Water absorbs three times its bulk of this gas, and acquires the same disagreeable odour. A saturated solution of this gas in water, also reddens some vegetable infusions. Such water deposits sulphur on keeping; sulphur is also precipitated by the addition of a few drops of nitric acid to the watery solution; the oxygen of the acid combining with the hydrogen of the gas, the sulphur is set free.

Sulphuretted hydrogen may be decomposed by a succession of electrical sparks, by the voltaic flame, by detonation with oxygen, and by being

brought into contact with chlorine, iodine, or potassium. In the latter case, when the metal is heated in the gas, it absorbs sulphur, and pure hydrogen remains. The decomposition of this gas by iodine, affords the easiest method of obtaining hydriodic acid, which is of some importance on account of its property of producing beautiful colours, by combination with some of the metals; with solution of muriate of tin, it produces a fine orange, and with that of peroxide of mercury, a beautiful red. Hydriodic acid may be readily obtained by passing sulphuretted hydrogen through a mixture of water and iodine; the excess of sulphur will be drawn off by evaporation, and liquid hydriodic acid will remain.

The solution of this gas in water is clear and colourless, and affords a most delicate test for detecting metallic substances in solution; it precipitates them of different colours, by which they may be distinguished.

One hundred cubical inches of sulphuretted hydrogen gas weigh thirty-six grains, and its specific gravity is to that of hydrogen as 17 to 1; it is believed to be composed of one atom of hydrogen and one atom of sulphur; its atomic number being 17. Bisulphuretted hydrogen is composed of two atoms of sulphur and one of hydrogen; its number is, therefore, thirty-three

When sulphuretted hydrogen is passed through solutions of alkaline or earthly bases, or through water containing mixtures of insoluble bases, *hydro-sulphurets* are formed. These substances are all soluble in water, they are mostly capable of crystallizing, and solutions of them precipitate metallic substances of characteristic colours.

PHOSPHORUS is a highly combustible substance which, when pure, is almost transparent and colourless, and it is soft and flexible. When air is excluded it melts at 105° of Fahrenheit and at 550° it boils, exhaling fumes that are luminous. Its specific gravity is 1.77, and its atomic number 15.71.

Phosphorus may be prepared by distilling in a coated earthen retort at a red heat, a mixture of concrete phosphoric acid with half its weight of charcoal. The retort is put into a small furnace, and the tube of it is immersed in a bason of water. A quantity of gas, some of which inflames, first comes over; when the retort has attained a full red heat, a reddish waxy looking substance passes over, which is impure phosphorus. To purify the phosphorus thus obtained, it is melted, and pressed through a piece of chamois leather, and is then cast into sticks by pouring it into tubes under water. The best coating for the retort in this process, is a mixture of slaked lime, and solution of borax; two or three coats of which laid on with a brush, will, when heated, form a strong vitrified covering.

Ex. 50. Phosphorus burns brilliantly in common air, but much more so in oxygen gas. When a small piece of it is inflamed and plunged into a vessel containing oxygen, the combustion is very rapid, and it is attended by an exceedingly brilliant and beautiful light.

When phosphorus is heated in a vessel which has been exhausted of part of its air, it enters slowly into combination with oxygen, forming three distinct compounds; a red solid, not so fusible as phosphorus, which seems to be a mixture of phosphorus and oxide of phosphorus; a white volatile substance which is phosphorous acid; and a white substance so fixed that it does not evaporate at a white heat, which is phosphoric acid. There is another compound of phosphorus and oxygen, which is called hypophosphorous acid.

Phosphorous acid may be obtained in the form of a white crystalline solid, by filtering and evaporating a solution of chloride of phosphorus in water. It is very soluble, and has a sour taste. The combinations of this acid with bases, are called phosphites; they are not very important.

Phosphoric Acid may be procured by burning phosphorus in excess of oxygen gas, or under a dry receiver full of common air; a deliquescent white substance will appear on the inside of the receiver. It may be obtained by exposing phosphate of ammonia to a red heat, in a platinum

crucible, or it may be prepared by acting upon phosphorus by nitric acid. The acid being heated by a sand heat in a tubulated retort, attached to a tubulated receiver, drop some small pieces of phosphorus into the acid, and suffer the nitrous gas that will be first produced to escape, by leaving out the stopper; the stopper must then be put in loosely and the heat continued until the liquid in the retort becomes thick like syrup; it must be farther evaporated by giving it a red heat in a platinum crucible, it will then be pure phosphoric acid.

A more economical process is adopted in preparing this acid for the manufacture of phosphorus. A mixture of twenty pounds of bones, calcined to whiteness, and pulverized, twenty quarts of boiling water, and eight pounds of sulphuric acid, diluted with the same weight of water, must be well stirred together and allowed to stand twenty-four hours, or simmered for six hours. It is then strained through a linen bag, and evaporated in earthen vessels, by a sand heat, to half its bulk. The white sediment that forms is allowed to subside, and the clear solution is poured into a glass vessel, and evaporated to dryness, a white mass remains; this substance being melted in a platinum crucible, and cooled in a copper vessel, assumes the appearance of transparent glass, and consists of phosphoric acid contaminated by some sulphate and some phos-

phate of lime. When pure its specific gravity is two, and it is believed to be a compound of one proportion of phosphorus with two of oxygen.

Phosphate of ammonia results from the saturation of phosphoric acid with ammonia.

Phosphorus combines with chlorine in two proportions, forming the chloride and bi-chloride. The first is produced by distilling a mixture of phosphorus and corrosive sublimate; it consists of one proportion of each: and the second by submitting phosphorus to the action of chlorine; it burns with a pale flame, and per-chloride results: it is composed of one proportion of phosphorus and two of chlorine.

Phosphorus combines with iodine, forming iodide of phosphorus, which acts upon water, energetically decomposing it, and forming hydriodic and phosphorous acids. There is another compound of iodine and phosphorus, which is called the *per-iodide*. According to M. Gay Lussac there are three compounds of these substances.

Ex. 51. Phosphorus combines with hydrogen to form *phosphuretted hydrogen*. The most usual method of preparing this gas is by heating some phosphorus in a solution of caustic potash. The retort should be quite full, and when the gas is to be allowed to escape into the atmosphere, the retort should be secured, and its beak immersed

in a small vessel containing a portion of the same solution within the retort.

This gas takes fire immediately on coming into contact with the atmosphere, producing rings of dense white smoke, enlarging as they ascend.

The experiment is still more beautiful when the bubbles of phosphuretted hydrogen are permitted to ascend into a vessel filled with oxygen.

Ex. 52. The experiment may be varied by mixing five parts of water, three of sulphuric acid, one of granulated zinc, and half a part of phosphorus, in a wide glass vessel; the gas is rapidly, and for a length of time, set free in small bubbles, which inflame over the whole surface of the liquid.

Ex. 53. Another easy process for obtaining this gas, is to fill a small retort with water, acidulated by muriatic acid, and then to introduce some small lumps of phosphuret of lime; the retort being connected with a jar, over water, phosphuretted hydrogen gas may be collected in considerable quantity. Seventy cubical inches of the gas may be obtained from half an ounce of the phosphuret.

This gas is considered to be a compound of one proportion phosphorus and one hydrogen: one hundred cubical inches weigh twenty-seven grains. It is colourless, and has an excessively disagreeable smell.

There is another compound of phosphorus and hydrogen, which was discovered by Sir H. Davy in 1812, and called by him hydrophosphoric gas; it is now usually named sub-phosphuretted hydrogen. It explodes when heated with oxygen, and burns spontaneously in chlorine. It is composed of two proportions hydrogen and one phosphorus.

Phosphorus and sulphur unite in several proportions. Two parts of the former to one of the latter make the most fusible compound, remaining liquid at 40° of Fahrenheit. This compound, the proportion of sulphur being rather larger, makes an excellent composition for fire bottles, the smallest particle of it being taken out upon a common sulphur match, and rubbed upon a piece of cork instantly takes fire. Another method of making phosphorous fire bottles is to stir some phosphorus in a small bottle with a red hot wire, until it is all converted into an oxide; to obtain fire a small portion is taken out upon a common match, and rubbed upon cork. The bottles used for these purposes must be close corked when not in use.

CARBON exists in its state of greatest purity in the *diamond*: this beautiful and highly valued substance is found in alluvial soil, of different crystalline forms, and of different colours: those without colour are the most valuable.

It would perhaps be impossible to find sub-

stances more dissimilar in appearance than diamond and charcoal, although their chemical nature has been proved to be the same. The diamond is combustible, and when burned in oxygen gas, it changes the oxygen into carbonic acid gas. Diamond heated in contact with iron converts it into steel.

The common form of carbon is *charcoal*. Lamp-black is the purest variety of charcoal. Charcoal may be prepared by filling a vessel, capable of sustaining heat, with small pieces of any kind of wood, the whole being covered over with fine sand so as to exclude the air; the vessel must be kept at a red heat for about an hour, and then permitted to cool before the charcoal be taken out. The chemical properties of this substance will be the same whatever wood may be used.

On a large scale charcoal is prepared by forming it into piles of a conical form, which are covered with clay to exclude the air; no more air being admitted than is necessary to maintain the combustion. Small wood is generally used being least valuable.

For some purposes, such as the manufacture of gunpowder, charcoal is best prepared by being submitted to distillation in close iron vessels. Charcoal is a bad conductor of heat, but a good conductor of electricity.

Charcoal recently prepared is capable of absorbing large quantities of different gases without

changing them. According to the experiments of Saussure, one volume of box-wood charcoal, absorbs of

Ammoniacal gas	90 volumes.
Muriatic acid gas	85
Sulphurous acid	65
Sulphuretted hydrogen	55
Nitrous oxide	40
Carbonic acid	35
Olefiant gas	35
Carbonic oxide	9.42
Oxygen	9.25
Azote	7.5
Hydrogen	1.75

Charcoal prepared from different kinds of wood has different degrees of absorbing power; and it has been found that the greatest absorption had always taken place in twenty-four hours.

Charcoal has the remarkable property of destroying the taste, colour, and smell, of many animal and vegetable substances. Vinegar boiled with charcoal becomes limpid. The colour and flavour peculiar to rum, and other varieties of spirituous liquors, may be removed by maceration with powder of charcoal.

Charcoal resists putrefaction so powerfully, that a piece of tainted meat may be rendered sweet by rubbing it daily with charcoal powder;

and meat will keep for a long time surrounded with pounded charcoal, which is daily renewed. Putrid water may be freshened by agitation with charcoal; and water may be prevented from becoming putrid in casks, by charring the insides of them. Contaminated air and putrid animal fluids may be purified by charcoal.

Charcoal being a very bad conductor of caloric, it is used, with good effect, for surrounding bodies, the heat of which requires to be confined.

Carbon, the atomic number of which is six, unites with oxygen in two proportions, to form *carbonic oxide* and *carbonic acid*.

Ex. 54. *Carbonic oxide* is readily prepared for experiment by acting upon carbonic acid, by any substance capable of depriving it of a portion of its oxygen; as by heating chalk and charcoal together in an iron bottle; or a mixture of chalk with the same weight of iron or zinc filings. Equal proportions of oxide of zinc and charcoal heated together will produce it: but it is obtained in greatest purity by the following process: fill a small earthen retort with equal parts of carbonate of barytes and clean iron filings, apply a red heat, and collect the gas, after permitting the first portions that come over to escape. The gas when well washed with lime water will be pure.

This gas cannot support life or combustion : in the air it burns with a pale blue light.

Two volumes of this gas, mingled with one of oxygen, and exploded by the electric spark, produce two volumes of carbonic acid.

Potassium heated in a retort with this gas, combines with its oxygen, and carbon is deposited in the form of black powder.

Carbonic oxide consists of one proportion carbon, and one proportion oxygen. Its number is fourteen.

Carbonic oxide combines with chlorine to form *chloro-carbonic acid*, or phosgene gas.

Carbonic acid results when carbon is burned in oxygen gas. Diamond or charcoal produces the same effect. As the volume of gas remains the same after the combustion, the quantity of carbon which has entered into combination, is indicated by the increased weight of the gas. It is composed of one proportion of carbon, and two proportions of oxygen: one hundred cubical inches of it weigh 46.57 grains. Its atomic number is 22.

It was proved in 1797, by Mr. Tennant, that the same results were obtained by submitting equal weights of diamond and charcoal to the action of red-hot nitre. And the experiments of Messrs. Allen and Pepys, in 1807, afforded satisfactory proof that diamond and charcoal,

burned in pure oxygen gas, give exactly the same results, producing carbonic acid gas.

This gas extinguishes burning bodies so effectually, that if a burning taper be plunged into a bottle of it, it is extinguished as soon as it enters the bottle; even the ignition of the wick is instantly destroyed.

Ex. 55. But it is not by burning charcoal in oxygen that this gas is best prepared for experiment; it is most readily obtained by the following process: into a glass retort or gas bottle, fig. 43, put some bruised marble, (carbonate of lime) or chalk, and add muriatic acid, diluted with water. The muriatic acid combines with the lime of the marble or chalk, and sets the carbonic acid free, which may be received over water. The gas comes over with great rapidity without the aid of heat.

Ex. 56. The effect of this gas upon burning bodies may be pleasingly contrasted with that of oxygen: fill one wide-mouthed bottle with each gas, put a burning taper into a third bottle, and pour in as much carbonic acid gas as may be sufficient to put out the taper, without destroying the ignition of the wick, then plunge the taper into the bottle of oxygen, it will be relighted with a slight explosion; and in this way, being introduced alternately into the carbonic acid gas and the oxygen, it may be extinguished and lighted again a number of times.

At the usual pressure of the atmosphere, water absorbs its own volume of carbonic acid gas ; it combines with two volumes under a pressure of two atmospheres, and larger proportions as the pressure of the air is encreased. Water thus saturated with gas tastes sour, and delicate vegetable blues are reddened by it.

The apparatus, fig. 44, which is called Nooth's apparatus, is used for impregnating water with carbonic acid gas, so as to imitate Pyrmont and other mineral waters that derive their effervescent quality from the quantity of this gas which they contain. The lower vessel, *a*, contains the materials for producing the gas, and has an aperture by which they may be introduced ; the gas passes through a valve in the tube of the vessel, *b*, and passing through the water in that vessel, presses upon its surface, and makes it ascend into the uppermost vessel, *c*. The uppermost vessel has a heavy stopper, which answers the purpose of a valve, preventing the gas from escaping until it exerts considerable pressure. The water, when it has a sufficient quantity of gas condensed into it, may be withdrawn by the stop-cock, *d*.

For making good soda water greater pressure is required ; this is usually obtained to the amount of five or six atmospheres, by the use of a strong barrel and a forcing pump.

It is to carbonic acid gas that fermented liquors owe their briskness.

This gas is produced by the processes of burning and breathing, in great quantities, and would, if it were to mingle with the air in the proportion of a tenth part of the whole, render it unfit for the purposes of life. But this heavy compound of oxygen and carbon is copiously imbibed by plants, which decompose it, retaining the carbon and setting free the oxygen.

Many fatal accidents have been occasioned by persons breathing this gas. It collects, on account of its great weight, at the bottom of mines and deep wells, and is known by the name of choke damp. Persons descending incautiously into such places sometimes inspire the gas, become insensible, and fall from the ropes or ladders by which they descend; others going down to their assistance, have often shared the same fate. A burning candle should first be let down, if the candle continues to burn, the place may be explored in safety; but if the candle is extinguished, it will be dangerous to descend, until, by dashing down water, the carbonic acid is made to mix with the air, and effect its escape; this may be ascertained by trying again with the candle.

This gas being a product of fermentation, exists over fermenting liquors in brewers' vats; and persons have lost their lives in consequence of leaning incautiously over their sides.

Charcoal fires in close apartments are very dangerous, for the carbon of the charcoal com-

biner with the oxygen of the air, and converts it into carbonic acid gas, which has frequently occasioned death under such circumstances. Carbonic acid gas has been condensed into a liquid under a pressure of forty-two atmospheres.

Several striking experiments may be shewn illustrative of the great weight of carbonic acid gas. If a burning taper be put into a small vessel, it will go out as soon as some of this invisible gas is poured upon it from a bottle; and the taper, if lighted again, will not burn in the vessel into which the gas was poured, until it is poured out. A small animal dies very quickly when some of this gas is poured into a vessel containing it. It is a very convenient way of killing butterflies, and other insects, the colours of which are to be preserved, to put them into a bottle of this gas. When this gas exists in a cavern or well, portions of it may be drawn out in a pitcher, let down into it; and when it exists in a vat or other vessel, it may be drawn by a stop-cock.

There is a cave in the side of a mountain, near the lake Agnano, in the kingdom of Naples, which has been famous for many ages on account of a stratum of carbonic acid gas that covers its bottom; a person may go in without danger, but a dog, having his nostrils near the ground, inspires the gas, and is killed by it in a short time.

Carbonic acid is decomposed by burning po-

tassium in it; the potassium combines with the whole of its oxygen, and charcoal is deposited.

Ex. 57. Carbonic acid combines with ammonia to form *carbonate of ammonia*. One volume of carbonic acid and two volumes of ammoniacal gas, being mingled, condensation ensues, and a white solid substance is produced, which is the well-known salt used for filling smelling bottles, with the addition sometimes of an odoriferous oil. It has a pungent odour and a saline taste. It converts vegetable blues into green.

Carbonate of ammonia is best produced by sublimation in an earthen vessel, from a dry mixture of muriate of ammonia and carbonate of lime.

Carburetted hydrogen being mixed with chlorine in excess, a white crystallized substance, having an aromatic smell, like camphor, is formed, which is *chloride of carbon*. It is not important.

Carburetted hydrogen, or olefiant gas, is formed by the union of one proportion of each, carbon and hydrogen.

Ex. 58. It may be obtained by heating in a retort, connected with the hydro-pneumatic apparatus, one part of alcohol and four parts of sulphuric acid, the gas will come over in considerable quantities. It derives its name of olefiant gas from its forming an oily looking substance when mixed with chlorine over water. The alcohol is decomposed in this process, and the

hydrogen and carbon, of which it is constituted, unite to form carburetted hydrogen. This gas is combustible, burning with a beautifully brilliant light, producing, by its combustion with oxygen, carbonic acid and water. This gas has resisted the utmost efforts to condense it into a liquid.

When a burning taper is applied to a mixture of one volume of carburetted hydrogen with two volumes of chlorine, it is inflamed, muriatic acid is formed, and carbon is deposited in the state of intensely black smoke.

A mixture of carburetted hydrogen with hydrogen, sulphuretted hydrogen, carbonic oxide, and other gases, which after it is purified has considerable illuminating power, and is extensively used for the purpose of illumination.

Subcarburetted Hydrogen often rises to the surface of muddy ditches or stagnant pools, and may be obtained by filling a wide-mouthed bottle with water, and inverting it under the surface of the stagnant water; the bottom of the pool, just under the mouth of the bottle being stirred with a stick. It is also called fire-damp in coal mines, where it occurs, and has often occasioned destructive explosions, which are now rendered less frequent by Sir H. Davy's Safety Lamp. This gas is composed of one proportion carbon and two hydrogen.

Carburet of Nitrogen, Cyanogen, or Prussine, is a compound of carbon and nitrogen: one hun-

dred cubical inches of it weigh 54.9 grains, and its specific gravity is to that of hydrogen as 24.4 to 1. To obtain it pure, dry cyanuret of mercury is heated to redness in a small glass tube; the gas is then evolved, and must be received over mercury. Its smell is penetrating, and resembles that of bitter almonds. It burns with a beautiful purple light. It is soluble in water, and its solution changes vegetable blues to red. A knowledge of its composition is obtained by detonating one volume of it with two volumes of oxygen over mercury: there result two volumes of carbonic acid, and one volume of nitrogen: from which it appears that cyanogen is composed of two proportions of carbon and one of nitrogen. Its atomic number is 26.

Cyanogen combines with chlorine to form *chlorocyanic acid*, which consists of one proportion of each.

Iodine being heated with cyanuret of mercury, *idiocyanic acid* is produced.

Hydrocyanic acid or Prussic acid, may be obtained by the following process. Some cyanuret of mercury must be put into a glass retort, in the neck of the retort there must be some pounded marble; a phial must next be adapted to the end of the retort as a receiver, and kept cold by a mixture of ice and salt. The cyanuret in the retort must be moistened with muriatic acid, and then gently heated. Hydrocyanic acid in the state

of vapour fills the retort, and condenses in the phial; while the muriatic acid produced in the process is seized by the carbonate of lime. In obtaining hydrocyanic acid by this process, it is necessary to be careful not to inhale any part of the vapour, on account of its poisonous quality. The liquid produced in this way is very volatile; its smell resembles that of bitter almonds, and it is a most virulent poison. A single drop of this acid put upon the tongue of a large dog, occasions instant death. The poison seems to destroy by affecting the nervous system, and death ensues before the heart ceases to beat. It reddens vegetable blues, and enters into numerous combinations. It is a compound of one proportion of cyanogen and one of hydrogen: and as cyanogen is composed of two volumes carbon and one volume nitrogen, the constituent parts of this acid are two volumes carbon, one volume nitrogen, and one volume hydrogen. Its number is 27. This acid exists in the essential oil of bitter almonds; so that it is very unfit to be used, as it frequently is, as a substitute for bitter almonds in cookery, being poisonous: bitter almonds are not considered wholesome on the same account.

Cyanogen combines with sulphur to form a compound called *sulphocyanic acid*, which is useful chiefly as a test of iron.

Carbon unites with sulphur when the latter is

made to pass over red-hot charcoal: it is called *sulphuret of carbon*. It may also be distilled at a moderate heat, from a mixture of sulphur and charcoal, in an earthen retort. The liquid sulphuret of carbon should be condensed in a receiver, surrounded with ice. It is colourless; and so volatile, that it produces extreme cold by the rapidity of its evaporation. The quicksilver may be frozen in a thermometer; the bulb of which is covered with fine cotton moistened with sulphuret of carbon, and exposed under the exhausted receiver of an air-pump.

BORON may be obtained from boracic acid, by heating two parts of potassium with one of the acid, previously melted, and reduced to powder. The mixture must be heated in a copper tube. The potassium attracts the oxygen of the acid, and sets the boron free, which is found by washing out the melted matter from the tube, and filtering it; the boron remains upon the filter, in the form of an insipid insoluble brown powder, which burns brilliantly in oxygen gas when heated to 600° , forming boracic acid. Its atomic number is 8.

This substance is important chiefly as forming boracic acid, which, in union with soda, constitutes borax; an article of extensive use in the arts.

We now come to the examination of metallic substances, constituting the third class of simple substances, with their compounds.

POTASSIUM was first made known by Sir H. Davy, who discovered it in 1807, by applying wires proceeding from a voltaic combination of 150 pairs of four-inch plates to a portion of pure potash moistened, and supported upon a disc of platina; oxygen gas was evolved at the positive pole, and brilliant metallic globules were produced at the negative pole. The quantity of the metal capable of being obtained in this way is exceedingly minute. Other modes of producing it in larger quantities were discovered in 1808. That which was adopted by Gay Lussac and Thenard, is in most general use in this country.

Ex. 59. The apparatus fig. 45, is the best adapted for the process. A is a furnace, the heat of which is sufficiently raised by a blast of air from a double bellows, entering at B; *cc* is a clean and perfectly sound gun-barrel, bent in the manner represented; the part which is on the inside of the furnace from D to *e*, is covered with an infusible lute; clean iron turnings are introduced into the inside of the luted part, and pieces of pure potash put into that part of the barrel between *e* and *c*. FF are copper tubes joined to the gun barrel by grinding. G and H are glass tubes that dip into vessels of mercury. The apparatus being thus arranged, the tube within the furnace is brought to a white heat. The escape of air by the tube G proves that the whole is sufficiently tight. The wire

cage I, containing burning charcoal, is then applied, the potash is melted, and gradually runs down upon the iron, which attracts its oxygen; potassium is disengaged, and collects in the barrel and tubes at D and FF. While the process is going on, hydrogen escapes by the tube H, and the heat applied to the potash should be in such degree as to make it flow down upon the iron very gradually; if it is melted too fast, the circumstance will be indicated by the too rapid escape of hydrogen gas. The tubes FF must be kept cool by the application of wet cloths. At the conclusion of the process, the tubes g and h are to be taken out, and the apertures from whence they were taken, closed very tight with corks. When the whole is cold, the barrel may be removed, and a little naphtha poured through it, to cover the surface of the potassium, and prevent the action of the air upon it; the potassium is then to be removed, and immersed in naphtha.

Mr. Curandau, of Geneva, recommended another process, which is much used on the Continent, and by which it is affirmed, potassium may be obtained with great facility, and in considerable quantities. Potash and charcoal being put into a strong iron pot, a bent iron tube is attached, and heat is applied. It is said, that the Swedish chemist, Berzelius, made half a pound of potassium at once by this method.

Potassium has a white colour and brilliant

lustre, but tarnishes as soon as it is exposed to the air; it is ductile and soft, and lighter than water. It is best kept in a closely corked bottle, moistened with naphtha. Potassium is a conductor of electricity and heat. It has so strong an attraction for oxygen, that it decomposes air to obtain it; and when it is thrown upon water, it floats about upon the surface with great rapidity, decomposing the water, combining with its oxygen, and setting free the hydrogen, which inflames.

When a portion of vegetable blue liquid, obtained by infusing the leaves of red cabbage in boiling water, is used for this experiment, it is changed to green; because the potassium combining with oxygen forms potash, which, being dissolved in the liquid, changes the vegetable blue to green.

A small piece of potassium thrown upon a piece of turmeric paper, moistened with water, moves about upon the paper, reddening the part over which it passes.

Potassium readily takes fire on being rubbed by a piece of wood on brown paper: it burns in oxygen with great brilliancy. The atomic number of this metal is 40.

Protoxide of Potassium. Potassium combines with oxygen in two proportions, is composed of one proportion of oxygen and one proportion of potassium. Its atomic number is therefore 48.

It has been ascertained, that one hundred parts of potassium, combine with twenty parts of oxygen to form the protoxide of potassium.

Peroxide of potassium is formed by heating the metal in excess of oxygen. It is formed of one proportion potassium and three oxygen, making its atomic number 64.

Hydrated protoxide, or caustic potash, is obtained by decomposing carbonate of potash by lime. The carbonate is boiled in a clean iron vessel, with half its own weight of quick-lime and water. The ley must be strained through clean linen, concentrated by evaporation, and again strained; it should then be set by in a well-stopped bottle, until it admits of being poured out quite clear. This clear solution must be evaporated to dryness. When prepared for sale, it is usually cast into sticks; it is in that state used as a caustic. Remaining impurities may be separated from it by alcohol, which dissolves the pure hydrate, and leaves the impurities undissolved. The alcohol is then driven off by heat, and the potash is enclosed in well-stopped bottles.

Chlorine combines with potassium with great energy to form *chloride of potassium*, which crystallizes in cubes.

Chlorate of potash is prepared by making chlorine pass from a retort in which it is prepared, through a solution of carbonate of potash, in a

series of Woolfe's bottles; the chlorine combines with the potash, and the carbonic acid escapes. When the solution is saturated with chlorine, it should be set aside in a cold dark place, where it will deposit crystals, which, after being drained, should be dissolved in hot water; the salt will be deposited again, when the water cools, in white crystalline scales.

This salt is a compound of six proportions of oxygen, one of chlorine, and one of potassium.

This saline substance heated to redness in a small glass retort, gives out very pure oxygen gas.

It acts with great energy upon many inflammable substances. Three parts of the chlorate mixed with one of sulphur, struck with a hammer, or rubbed in a mortar, explodes with great violence.

It explodes with dangerous violence when triturated with phosphorus.

One part of this salt being mixed in a mortar, with one part of lump sugar, and put upon a piece of wood, a drop or two of sulphuric acid let fall upon the mixture, makes it burst into a beautiful flame. It is with similar materials that the matches for obtaining instantaneous light are prepared. Small slips of wood, proper for the purpose, are first dipped into sulphur, and then into a fused mixture of chlorate of potash and lump sugar, coloured with a little vermillion;

one of these being suddenly dipped into a small bottle containing sulphuric acid, it is instantly inflamed. A little asbestos is put into the bottle to prevent the acid from being spilled.

Berthollet proposed the substitution of this salt for nitre in gunpowder, and an attempt to manufacture gunpowder in this way was made at Essone, in 1778. The sulphur and charcoal mixed with the chlorate, being submitted to trituration, the whole exploded, and occasioned the death of several persons.

An excellent bleaching liquid may be conveniently made by pouring a little muriatic acid upon a few grains of this salt, and diluting with water; almost every kind of stains yield to it readily.

Perchlorate of potash is a compound of perchloric acid and potash.

When potassium is burnt in the vapour of iodine, a compound results which is *iodide of potassium*.

Potassium combines with hydrogen, producing two compounds, one a solid called *hydruret of potassium*, and the other a gas called *potassurated hydrogen gas*.

Nitrate of potash commonly called *nitre* or *saltpetre*, is a compound of nitric acid and potash. It is obtained in France and Germany, by collecting the rubbish of old buildings into heaps, mixed with animal and vegetable matter, in dry

ditches; these heaps, which are called nitre beds, are exposed to the atmosphere, but protected from rain, and they are kept a little moist with urine. On washing the materials of these heaps with water, at the end of a year or two, a solution of nitre is obtained, which being evaporated, affords the salt in a solid state.

It is produced in considerable quantities in Spain, by lixiviating calcareous soils, abounding in decayed animal matter: the salt existing ready formed in these soils is nitrate of lime, but it is converted into nitrate of potash, by mixing wood ashes or carbonate of potash with the solution. It seems that nitric acid is produced in all places, impregnated with decomposing animal matter, where there are free currents of air, and substances with which the acid can enter into combination; as on calcareous ground much mixed with the excrements of cattle; on the walls and other parts of places where putrid animal effluvia are continually arising, as drains and slaughter houses.

The inhabitants of France made good use of these means of obtaining nitre, at the commencement of the revolutionary war, when they experienced difficulty in obtaining from the usual sources sufficient supplies of this article for the manufacture of gunpowder.

Saline exudations of this kind are often found upon new walls, arising, it is supposed, from

the decomposition of animal matter contained in the mortar.

But the chief supplies of this important substance are imported from the east, where it is found mingled with the soil of extensive districts, and prepared for commerce by lixiviation and evaporation.

The ultimate component parts of this salt are six proportions of oxygen, one of nitrogen, and one of potassium. It has a peculiar taste, and produces a sensation of extreme cold when put upon the tongue. It may be fused without undergoing alteration, but when exposed to a white heat, it is decomposed into oxygen, nitrogen, and potash. The cakes which are formed by fusing this salt, and casting it into moulds, are called *sal prunelle*.

It is easy to decompose this salt by mixing it with charcoal, and submitting the mixture to a red heat; the results are carbonic oxide, carbonic acid, nitrogen, and sub-carbonate of potash.

When sulphur is thrown upon red-hot nitre, it combines, producing sulphite and sulphate of potash.

Rapid and brilliant combustion takes place when phosphorus is brought into contact with hot nitre, and the result is phosphate of potash.

Ex. 60. Beautiful appearances are produced by projecting small portions of almost any of the metals, in a finely divided state, such as powder,

or filings, into red-hot nitre. Some of them detonate, and most of them burn brilliantly.

A fulminating compound may be produced by mixing well together, two parts of dry sub-carbonate of potash, and three parts of nitre. A small quantity of which laid upon any iron plate, such as a fire shovel, and held over the fire, blackens, begins to melt, and at the same moment explodes with considerable noise.

The mixture called *the powder of fusion*, is prepared by mixing thoroughly one part of sulphur, one part of fine sawdust, and three parts of nitre, previously freed from its water of crystallization by heat.

Ex. 61. If a piece of copper, such as an old coin, be laid upon a quantity of this mixture pressed down into a walnut shell, and the mixture be set on fire, the copper will be melted into a globule without burning the shell. The effect produced in this experiment is in a great measure owing to the action of the sulphur on the metal forming a metallic sulphuret.

Nitre is useful in a great variety of ways; it is an essential ingredient in some fluxes; it is extensively used in the manufacture of sulphuric acid; it is used by dyers; it is used for preserving meat, to which it imparts a red colour; it is used in chemistry for producing cold, and for many other purposes; and in medicine it is prescribed as cooling, febrifuge, and diuretic.

Another important purpose to which nitre is applied is the manufacture of gunpowder, into the composition of which it enters as the chief ingredient. The proportions of the ingredients of gunpowder are different, according to the use for which the powder is intended, as will be seen by the following table.

	Common Powder.	Shooting Powder.	Shooting Powder.	Miner's Powder.
Saltpetre	75.0	78	76	65
Charcoal	12.5	12	15	15
Sulphur	12.5	10	9	20

The materials must be intimately blended together by long trituration in wooden mortars, moistened with a little water. This operation is performed in the large way by a mill, which gives motion to the pestles of ranges of wooden mortars. The pounding is usually continued twelve hours, before the mixture is considered complete. It is then granulated by being forced through wire sieves, by which it is cut into small grains, which are afterwards dried, and polished by rolling in a cylindrical vessel.

The force of gunpowder depends upon the sudden extrication of gaseous matter, consisting of carbonic oxide, carbonic acid, nitrogen and sulphurous acid, produced by the action of the nitre and the combustibles upon each other. Charcoal made from light woods, and not com-

pletely burned, is considered the best adapted for this purpose.

Potassium and sulphur act energetically upon each other, producing considerable light and heat, while they combine to form *sulphuret of potassium*, which is composed of one proportion of sulphur, and one of potassium. The same substances also combine to form *bisulphuret of potassium*, in which there is twice the quantity of sulphur that exists in the former compound.

When potash and sulphur are melted together, a *red sulphuret of potash* is formed, which is known by the name of *liver of sulphur*.

The compounds *hyposulphite* and *sulphite of potash*, are unimportant.

Sulphate of potash results from the combination of sulphuric acid and potash, and may be formed by adding these together to saturation. It is capable of being dissolved by sixteen parts of cold, and five parts of hot water; it has a bitter taste, and crystallizes in short six-sided prisms, with six-sided terminations. It melts with a red heat, but remains unaltered in its chemical constitution.

Bi-sulphate of potash may be prepared by boiling sulphate of potash in sulphuric acid. The salt obtained is used by jewellers for cleaning plate, and it is used for cleaning many other kinds of metals.

There are several other combinations of potash,

so unimportant that they need not be described; but the compounds of potash and carbonic acid are of great importance in the arts; there are two of them, the carbonate and bi-carbonate.

Carbonate of potash is known in its different states of purity by the name of wood ashes, potash, pearlash, and subcarbonate of potash.

This important article of commerce is obtained from the ashes of burned vegetables, and it is manufactured chiefly where there is a great abundance of wood; the largest supplies are obtained from North America. It will be seen by the following table that the ashes of herbaceous plants yield more of the carbonate.

TABLE of the saline products of one thousand pounds of ashes of the following vegetables.

Stalks of Turkey wheat, or maïse	198 lbs.
Stalks of sunflower	349
Vine branches	162.6
Elm	166
Sallow	102
Oak	111
Aspen	61
Beech	219
Fir	132
Fern cut in August, about . .	120
Wormwood	748
Fumitory	360
Heath	115

In order to obtain the largest quantity of pearl-ash from the combustion of plants, the following directions have been given.

Cut the plants just before they seed, dry them, burn them on a grate within doors, and put the ashes in some close place as soon as they are produced, as a box or barrel. When the burning is complete, lixivate the ashes with twelve times their weight of boiling water, until all the alkaline substance is extracted, which may be ascertained by trying the water last added to the ashes, by a drop or two of a solution of corrosive sublimate; evaporate the ley to dryness in iron pans; the substance in this state is called potash, then heat the mass obtained in a reverberatory furnace, so as not to fuse it, by which it will lose about fifteen per cent. of its weight, and be converted into pearl-ash of commerce.

This substance is usually contaminated with various others. Sulphate of potash, muriate of potash, insoluble matter, and water, so that different samples vary exceedingly in value. Sulphate of potash may be detected in solution by muriate of barytes, and muriate of potash by nitrate of silver; but the surest method of ascertaining the value of pot or pearl-ash of commerce, is founded on the property which acids and alkalies possess of saturating and neutralizing each other. By reference to Dr. Wollaston's scale of chemical equivalents, it will be

seen that seventy-one parts of strong sulphuric acid, neutralize one hundred parts of pure carbonate of potash. To ascertain the strength of any sample of pearl or potash of commerce, weigh accurately one hundred grains of it, and dissolve it in a sufficient quantity of water, then put seventy-one grains of sulphuric acid into a glass tube, graduated into one hundred equal parts, and fill up with water, taking care that the acid and water are well mixed; then add carefully and by degrees the acid solution to the alkaline, until the latter is quite neutralized, and the mixture is incapable of reddening turmeric paper; and to ascertain that acid has not been added in excess, try the mixture with a piece of litmus paper; if it is not reddened you will have attained the exact point of neutralization, and by looking how many of the hundred equal parts of acid solution remain after the neutralization of the alkali, you will see how much the sample under trial falls short of the saturating power of pure carbonate, or sub-carbonate as it is called. Thus, if forty measures of the acid solution remain, you may be assured that the alkali contains forty per cent. of impurities. Twenty measures remaining of the acid solution indicates that the sample under examination contains eighty per cent. of alkali and twenty per cent. of impurity.

Carbonate of potash may be obtained directly by passing carbonic acid through a solution of

potash, the liquid being evaporated to dryness, the mass remaining must be submitted to a red heat. This substance possesses the peculiar properties of alkalies, changing vegetable blues to green, and yellows to red; and is composed of one proportion of carbonic acid and one of potash.

Bi-carbonate of potash is composed of two proportions of acid and one of potash; it is but slightly alkaline.

Boron and potassium unite; but their compounds have been but little examined, and are not considered important.

SODIUM. The existence of this metal was discovered by Sir H. Davy, a few days after he discovered potassium, in October, 1807. It may be obtained by the same processes that are used for procuring potassium; but it is obtained with rather more difficulty. In many respects it resembles potassium: it has a silvery whiteness, great lustre, and conducts electricity. It melts at 200° Fahrenheit, and assumes the state of vapour at a red heat. It is a little heavier than potassium. It does not inflame when thrown on the surface of water, but effervesces violently, swimming about on the surface with great agitation, gradually diminishing as it combines with oxygen, converting the water into a solution of soda. Sodium is soft and malleable; when heated in air it takes fire and burns. In a limited

quantity of air its combustion produces protoxide of sodium; but when burned in excess of oxygen, orange coloured peroxide of sodium is formed. The former is found to be composed of one proportion of sodium 24, and one of oxygen 8, which, when combined with one proportion of water, constitute hydrate of soda. The peroxide of soda consists of one proportion soda, and one and a half of oxygen. Its atomic number being 36.

The combination of sodium, oxygen, and water, which is called soda, may be distinguished from potash by its forming an efflorescent paste; when exposed to the atmosphere, potash under the same circumstances deliquesces. Solution of potash produces a yellow precipitate when added to solution of muriate of platinum, Solution of soda occasions no precipitate. Excess of tartaric acid added to solution of potash occasions the deposition of crystals: added to solution of soda, it occasions no deposition.

When sodium is burned in chlorine, a white saline substance is produced, which is *chloride of sodium*, or common salt; it is composed of one proportion of sodium and one of chlorine.

This very important substance is found abundantly in Nature, in a solid state in the earth, and in solution in sea water. The mines of solid rock salt in this country are chiefly in Cheshire. The strata of salt are very solid, and of consider-

able depth. The common methods in use among miners for breaking rocks, are used in these mines for obtaining the salt; chiefly blasting with gunpowder. The salt obtained is mostly of a brownish colour, being contaminated with clay; it is purified by solution in water and evaporation in iron pans, from which it is drawn out, when crystallized, and put into baskets, and afterwards dried in stoves for sale.

It is also obtained by evaporation from sea water; but salt prepared in this way is generally contaminated with muriate of magnesia, which occasions it to attract moisture from the air and deliquesce. In other countries salt is obtained by exposing sea water to the heat of the sun's rays, which occasioning slow evaporation, the salt crystallizes in large crystals, and is called bay salt.

Beside the use of this article, in seasoning food and in curing provisions, it is extensively employed for many other purposes, of which a few of the most important may be mentioned. It gives hardness to soap; it improves the whiteness and clearness of glass; it is used as a glaze for pottery; and it is the never-failing source of soda and muriatic acid.

Chlorate of soda resembles chlorate of potash, and is obtained by the same process.

It is sufficient merely to name the following compounds of sodium and of soda: iodide of

soda, nitrate of soda, sulphuret of sodium ; and of soda, hyposulphate of soda, sulphite of soda.

Sulphate of soda, or Glauber's salt, is an abundant product of the process for manufacturing muriatic acid ; it is composed of one proportion soda, one sulphuric acid, and water.

Ex. 62. This salt is very much more soluble in hot than in cold water. If a saturated solution of it boiling hot be poured into a white glass bottle or flask with a long neck, until it is quite full, and the flask be then closed so as entirely to exclude the air, which is usually done by tying a double piece of wet bladder very tightly over the mouth of the flask ; the salt which the water will have dissolved when hot, over and above what it is capable of dissolving when cold, will not be able to crystallize under these circumstances. It is affirmed, that it cannot crystallize because of the exclusion of the pressure of the air ; but it frequently crystallizes when agitated without admitting the pressure of the air ; and sometimes when the air is admitted, it does not crystallize. So that its crystallization does not seem to depend entirely upon the pressure of the air. In general, when the solution is properly prepared, as soon as the covering is taken off crystallization begins at the top, and beautiful crystals, having the gloss and whiteness of satin, shoot downwards until the whole becomes nearly solid, forming a most

striking experiment. If a piece of string is tied round the neck of the flask to mark the place of the surface of the liquid before the crystallization begins, it will be seen to rise higher as that process goes on, and the flask with its contents will become quite warm; indicating the enlargement of bulk which crystallization occasions, and the evolution of latent heat attending that process. If crystallization should not begin on exposing the surface of the liquid to the pressure of the air, a small particle of the same kind of salt may be let fall into the flask, which will seldom fail to make crystallization commence; the particle will serve as a nucleus; it is usually arrested in its progress before it can pass far through the liquid, and crystals radiate from it in every direction throughout the whole mass in a most beautiful manner. A clear Florence oil flask will answer very well for this experiment, and the same solution may be made to serve a number of times, by putting the flask into a vessel of cold water, and making the water boil until the sulphate of soda is dissolved, and then closing the flask as before described.

Sulphate of soda may be decomposed by igniting it with charcoal and lime. The sulphuric acid combines with the lime, carbonic acid is formed, and unites with the soda.

The following compounds are unimportant: bi-sulphate of soda, ammonia-sulphate of soda,

phosphite of soda, phosphate of soda, and ammonia-phosphate of soda.

Carbonate of soda is composed of one proportion of soda and two of acid. It is manufactured for commerce by burning marine plants, as potash is by burning land plants.

Barilla is the ashes of the plant *salsola soda*, which is extensively cultivated on the sea coasts of Spain and other places. It sometimes contains as much as twenty per cent. of carbonate of soda.

Kelp is produced by burning sea weeds along the rocky shores of Britain and the western isles. It is sometimes burned in kilns, but more frequently in hollows in the ground. About twenty-four tons of sea weed are required to produce one ton of kelp, and it rarely contains more than five per cent. of carbonate of soda. The value of these substances may be ascertained by the same method as that recommended for ascertaining the value of pot and pearl ashes.

Bi-carbonate of soda is produced when carbonic acid is made to pass through a solution of carbonate; it consists of one proportion soda and four proportions acid. It is but slightly alkaline, being almost a neutral salt.

Boracic acid and soda are found combined, forming the salt called borax, which is chiefly imported from the East; but it is found also in South America, and in Europe. It is of great

use as a flux in experiments with the blow-pipe and in working in metals.

LITHIUM is the metallic base of the alkaline substance lithia. Sir H. Davy, in experimenting upon this substance, obtained proofs that it has a metallic base, bearing the same relation to it that potassium and sodium do to potash and soda ; but its properties have not yet been fully investigated. Its atomic number is 10.

Lithia was discovered by Mr. Arvedson, in a mineral called petalite. It is obtained by pulverizing the petalite minutely, and melting it with half its weight of potash ; muriatic acid must then be added, and the solution filtered and evaporated to dryness ; the next step in the process is to digest the mass in alcohol, by which the muriate of lithia will be dissolved ; carbonate of silver being added, the carbonic acid combines with the lithia, forming carbonate of lithia, which may be converted into pure lithia in the same way as the carbonates of potash and soda are converted into pure alkalies.

This substance possesses strong alkaline properties, and like the other alkalies, enters into a number of combinations, which, not being considered of much importance, they may be passed by.

CALCIUM was obtained by Sir H. Davy, by exposing a portion of lime to the action of a voltaic apparatus, in contact with mercury, and by

submitting the amalgam produced to distillation. Minute quantities of a white shining metallic substance were procured, which burned when a gentle heat was applied, and were converted into lime. Thus it is found that lime is a combination of calcium and oxygen. The atomic number of calcium is 20.

For chemical purposes lime is often prepared from fine white marble, which loses its carbonic acid when kept for a considerable time at a red heat, lime alone remaining. When required in a still more perfect state, the purest white marble may be dissolved in diluted muriatic acid, with the addition of a little ammonia. The solution must be filtered, and carbonate of ammonia added to it, which will occasion a precipitate; this precipitate must be washed, dried, and heated to whiteness,

Thus obtained, lime is a soft, greyish-white substance, extremely acrid and caustic, and possessing the alkaline property of changing vegetable blues to green. It is exceedingly difficult of fusion, yielding only to the flame of the oxyhydrogen blow-pipe, or to the intense heat produced by a powerful voltaic combination.

Water is not capable of dissolving more than $\frac{1}{750}$ th part of lime; and it is very remarkable, and contrary to analogy, that although water at 32° dissolves the above-named quantity, boiling water can only dissolve about half as much.

Lime water produces effects upon colours similar to alkaline solutions. It remains clear and transparent when not exposed to the air; but when air has access to its surface, it attracts carbonic acid; a film of carbonate of lime is formed which subsides, and is succeeded by another until the whole of the lime has entered into combination. On this account lime water is an excellent test by which to detect the presence of carbonic acid. The strong attraction of these for each other, may be pleasingly shewn, by breathing, with the aid of a glass tube, through a portion of clear lime water; the carbonic acid of the breath will combine with the lime, forming insoluble carbonate of lime, which occasions the clear liquid to become white and turbid. This experiment proves that carbonic acid is produced in the process of respiration; and it may be shewn that it is produced in the process of combustion, by burning a taper in a receiver of common air, containing some lime water at the bottom; carbonic acid will be formed, and the water will become turbid as before.

Lime water placed in a shallow vessel upon a little stand in another vessel containing sulphuric acid, and kept for a length of time under an exhausted receiver of an air-pump, evaporates rapidly, and at length deposits small six-sided prismatic crystals.

Lime, in its various states of combination, is

a very abundant natural production; united with carbonic acid, it constitutes chalk, limestone, and marble, which are of great utility for the purposes of the statuary, for building, and for burning into lime. Lime for common purposes is prepared by burning chalk or limestone in kilns, into which it is put with layers of culm or coal; a fire is lighted under, and the whole is kept at a red heat for a considerable length of time. As the lime falls to the bottom of the kiln it is let out, and other portions of limestone are thrown in above, and other layers of coal. In this process the carbonic acid is driven off, and the lime alone remains.

Lime is of great use in agriculture and in building.

When water is poured upon lime they combine together, forming hydrate of lime, and much heat is evolved; so that combustible bodies, such as sulphur and phosphorus, may be inflamed by the heat which is given out during the process of slacking quick-lime. Sand being mixed with quick-lime as well as water, the mixture is used for cement or mortar, in building; and acquires its hardness and solidity by its combination with carbonic acid, which it attracts from the air.

Although lime is fused with such difficulty when it is pure and unmixed, when mixed with other earths it fuses readily, and is on this ac-

count of great use as a flux in working metals, particularly in smelting iron, in which process it is extensively used.

Lime is used in preparing materials for making glue; in the manufacture of ammonia; in bleaching; in tanning; in the manufacture of soap; in sugar refining; and in a great many other processes in the arts.

Lime, or oxide of calcium, is composed of one proportion of calcium, 20, and one of oxygen, 8, making its atomic number 28.

Lime is capable of combining with a larger proportion of oxygen when it is heated in that gas; the combination that results is called *peroxide of calcium*.

Chloride of calcium may be obtained by the action of chlorine on lime, aided by heat; or by dissolving carbonate of lime in diluted muriatic acid, evaporating to dryness, and submitting the mass to a red heat in a close vessel.

This substance attracts water with great rapidity, so that it deliquesces quickly when exposed to the air. When mixed with snow great cold is produced.

Saturated solutions of chloride of calcium and sulphate of magnesia, added together, in about equal proportions, form a solid mass of sulphate of lime.

On account of the strong attraction of chloride

of calcium for water, it is frequently used for drying gases.

Chloride of lime is a very important compound, known under the name of oxymuriate of lime, or bleaching powder: mixed with water it forms a bleaching liquid. It is prepared upon a large scale by making chlorine gas enter into a close chamber, containing a great number of shelves, having wooden or leaden trays disposed upon them, containing hydrate of lime in fine powder. The apartment requires to be kept full of the gas four days before the lime is sufficiently saturated. In preparing the chlorine, ten cwt. of common salt is mixed with from ten to fifteen cwt. of manganese; to which mixture, after it is put into the alembic, twelve or fourteen cwt. of sulphuric acid is added by degrees. One ton of salt, with the other proper ingredients, are expected to produce one ton and a half of the bleaching powder.

The method usually adopted for trying the strength, and consequently the value of this powder, is to dilute sulphate of indigo with water, and ascertain how much of this solution a given quantity of the powder will deprive of its colour.

Chlorate of lime, iodate of lime, nitrate of lime, sulphuret of lime, and sulphite of lime, being unimportant, they need not be described.

Sulphate of lime is a very important substance

in the arts. It may be procured by saturating sulphuric acid with lime; but as it is an abundant natural production, there is no necessity to prepare it artificially. After being deprived of its water of crystallization, by baking in an oven, it is ground to fine powder, in which state it is called plaster of Paris, and is extensively used for the ornamental parts of the interiors of houses, for plaster casts, for making the moulds of stereotype plates, and many other purposes. The powder being mixed with water, to the consistence of cream, it is poured into moulds, previously oiled, and having the property of combining with water, it soon becomes hard, and may be removed, retaining the perfect impression of the mould.

Phosphuret of lime may be procured by the following process: into an earthenware or green glass tube, one inch in diameter, and about eighteen inches long, covered with a clay-lute, containing some borax, introduce about one ounce of phosphorus, broken in small pieces, let it slide down to the close end, and fill up the tube with quicklime, in pieces about the size of peas: pass the tube in an inclined position through a small furnace, so that the end containing the phosphorus may be out of the fire, while the other end is acquiring a red heat; the lower end of the tube must then be gently drawn into the fire, which will volatilize the phosphorus,

and make it pass through between the pieces of lime : by which the lime will be partly converted into phosphuret of lime. This is a difficult process, requiring a great deal of care : when it is completed the tube should be closed at the open end, and be allowed to cool. The phosphuret should then be withdrawn, and the brown pieces put into a well-stopped bottle for use. This substance decomposes water when thrown upon it, occasioning the evolution of phosphuretted hydrogen gas, which takes fire as soon as it comes into contact with air.

Phosphate of lime is one of the constituent parts of animal bones. Another compound of phosphorus and lime, with a large proportion of the former, is called bi-phosphate of lime.

Carbonate of lime has been already described, when it was mentioned as the source of quick-lime used in the arts.

Fluate of lime exists in a natural production of great variety, and sometimes of great beauty in its appearances, known by the name fluor-spar. It is supposed to consist of a substance not yet investigated successfully, called fluorine, united with calcium.

Hydrofluoric acid is believed to be a compound of fluorine with hydrogen. It may be procured by distilling in a silver or leaden apparatus, one part of pure fluor-spar, finely powdered, with two parts of sulphuric acid. The receiver must

be immersed in ice, to effect the condensation of the acid. It is void of colour; it has a very disagreeable odour; and it is so corrosive, that a drop of it instantly destroys the skin to which it is applied, occasioning a painful ulcer.

This acid corrodes glass with great rapidity, and it acts powerfully upon many of the metals.

Ex. 63. The process for etching upon glass by fluoric acid gas is easily managed. A piece of glass being covered with an even coat of bees'-wax, the figures to be imparted to the glass must be traced through the wax, with a sharp point for fine, and a blunt point for thick lines; provide a leaden trough adapted to the size of the glass to be etched, lay a piece of wood over it, so as to project a considerable way over all the edges; the part of the board which covers the inside of the trough must be cut out, this piece of board prevents the heat of the lamp, which is applied under the leaden trough, from heating the wax upon the glass. Fluor-spar, finely pounded, must then be put into the trough with as much sulphuric acid as may be required to moisten it thoroughly. Heat must be applied to the bottom of the trough, and the glass must be laid on the piece of wood, with its waxed side undermost, so as that the whole of the figured part may be exposed to the gas. Care must be taken not to apply the gas too long, and not to let the wax melt, otherwise the whole

surface of the glass would be corroded. In this manner, window panes may have any appropriate figures etched upon them; and drinking glasses may be ornamented with coats of arms, or any other figures, with very little trouble. The wax may easily be scraped and rubbed off.

Hydrofluat of ammonia, hydrofluat of potash, hydrofluat of soda, appear to be unimportant.

Fluoboric acid is prepared by mixing one part of fused boracic acid, and two of finely pulverised fluor-spar with twelve parts of sulphuric acid, and heating the mixture in a glass retort; the gas must be received over mercury. It acts powerfully upon animal and vegetable substances, and forms a class of compounds called fluoborates.

Barium has been obtained by submitting some barytes in contact with mercury, to the influence of the galvanic wires. It is more than twice as heavy as water, combines with oxygen very rapidly, and burns with a red light, forming oxide of barium. Its atomic number is 70.

Oxide of barium, baryta or barytes, is, when pure, of a greyish white colour, and fuses with great difficulty; it may be prepared by heating crystallized nitrate of baryta to a red heat, at which it must be kept some time. It is the heaviest of the earthy substances, its specific gravity being four; it renders syrup of violets green, and reddens infusion of tumeric. When water

is added, it slakes with the evolution of more heat than quicklime. Taken into the stomach it acts as a violent poison; being composed of one proportion of barium 70 and one of oxygen 8; its atomic number is 78.

Hydrate of barytes is a solid white substance, containing about ten per cent. of water, which being dissolved in water, crystals are deposited containing a larger proportion of water. Solution of hydrate of barytes changes vegetable blues to green.

Peroxide of barium is a compound possessed of twice as much oxygen as is contained in oxide of barium; it changes vegetable blues to green, and like other combinations of barytes, is highly poisonous.

M. Thenard formed a new compound of water and oxygen by dissolving peroxide of barium in muriatic acid, and precipitating by sulphuric acid; the process altogether is tedious and difficult; the product may be considered as *peroxide of hydrogen*. When applied to the tongue, it raises blisters, and has a peculiar metallic taste. When heated to nearly 212° , it is rapidly decomposed: most of the metals decompose it, some of them with the evolution of heat and light.

It is sufficient to name the following barytic compounds: chlorate of barytes, iodide of barium, iodate of barytes, nitrate of barytes,

sulphuret of barium, hyposulphate of barytes, sulphite of barytes.

Sulphate of barytes is the most abundant compound of barytes; it is known by the name of heavy spar or baroselenite. With a high degree of heat it melts into a white enamel. A very useful white colour, called permanent white, is an artificially prepared sulphate of barytes.

There are different methods in use for the purpose of obtaining pure barytes from its sulphate, which may easily be obtained in any quantity. One of these is to submit the crystallized sulphate, in fine powder, to a red heat in a silver crucible for half an hour, with three parts of carbonate of potash. The melted mass must be boiled in different portions of water, as long as any thing soluble can be extricated; the insoluble part must then be dissolved in dilute nitric acid, to produce nitrate of barytes, from which pure barytes may be prepared by the process already described.

Pure barytes may also be obtained from the sulphate by heating to redness in an earthen crucible or half an hour, a mixture of six parts of sulphate of barytes, in fine powder, with one part of powdered charcoal. The sulphate is changed into sulphuret of barytes, which must be dissolved in hot water, and mixed after it is filtered, with a solution of carbonate of soda, as long as it occasions a precipitate. This precipitate when

washed and dried is carbonate of barytes, which may be changed into nitrate, and the pure earth obtained from it as before.

Phosphuret of barium, hypophosphite of barytes, and phosphate of barytes are not important.

Carbonate of barytes occurs native, but in much less quantities than the sulphate. Dr. Withering first discovered it at Anglezark, in Lancashire, on which account it has received the name of Witherite.

The compounds of barytes are all poisonous, except the sulphate, which points out dilute sulphuric acid as the proper antidote for carbonate, and sulphate of soda for the soluble compounds of this earth.

Barytic compounds in solution are excellent tests for the presence of sulphuric acid.

STRONTIUM is a metal having less lustre than barium, which was obtained by a process similar to that used for obtaining the last mentioned metals; their properties being analagous. The atomic number of strontium is 44.

Strontia or oxide of strontium was first obtained towards the end of the last century, from a lead mine at Strontian, in Scotland, it has since that time been found in several other places. Pure strontia may most readily be obtained by heating nitrate of strontia to redness. It is of a greyish white colour, and an acrid and pungent taste, and imparts to alcohol the property of burning with a blood-red flame; being composed

of one proportion strontium and one oxygen, its atomic number is 52.

Strontia is not poisonous like barytes, it is much less soluble than that earth, and it is infusible.

Strontia is a principal ingredient of the red fire so often used at theatres, the composition of which is as follows: four parts of sulphuret of antimony, five parts of chlorate of potash, thirteen parts of finely powdered sulphur, and forty parts of dry nitrate of strontian. The sulphuret of antimony and the chlorate of potash, require to be pounded separately in a mortar, and mixed together on paper; they may then be added to the other ingredients, all of which require to be previously pounded. When the fire burns dimly, a little lamp black or finely powdered charcoal, is sometimes added.

The following combinations do not appear so important as to require description: chloride of strontium, chlorate of strontia, iodide of strontium, iodide of strontia, nitrate of strontia, sulphuret of strontium, hypo-sulphite of strontia, sulphite of strontia.

Sulphate of strontia has been found native at Strontian, in Scotland, near Bristol, and at other places: it is sometimes transparent and colourless, and sometimes it is of a bluish colour, and is called celestine. It is almost insoluble. Pure strontia may be obtained from it by a process similar to that by which barytes is obtained from sulphate of barytes.

Hypophosphate of strontia, phosphite of strontia, phosphate of strontia, are unimportant.

Carbonate of strontia was first successfully examined by Dr. Hope. It occurred at Strontian, but in small quantities, and is now very rare. When artificially produced, it is a white insoluble substance, which may readily be decomposed by heating with charcoal powder: carbonic oxide is formed and pure strontia remains.

Barytes and strontia strongly resemble each other in some respects, while they differ in others: the compounds of strontia are not poisonous like those of barytes. Strontia gives a red colour to flame, barytes a yellow colour.

MAGNESIUM has not been obtained as a separate metal, but appearances have been observed which lead to a conviction, that magnesia has a metallic basis. When the negative wire of the voltaic combination is applied to a portion of magnesia in contact with mercury, an amalgam is obtained which decomposes water by attracting its oxygen, and magnesia is formed.

Oxide of magnesium or magnesia, remains after carbonate of magnesia has been submitted for sometime to a red heat; it is white and tasteless, and produces a weak effect in changing vegetable blues to green. It has but a small degree of solubility in water, and is almost infusible.

Chloride of magnesium is produced by submitting red hot magnesia to a current of chlorine. When the substance thus obtained absorbs moisture it is changed into muriate of magnesia.

Muriate of magnesia is an intensely bitter deliquescent salt, which is found in some mineral springs, and in abundance in the water of the ocean, as will be seen by Murray's analysis of sea water. A pint of sea water, evaporated to dryness, leaves

	grains.
Common salt	180.5
Muriate of magnesia	23
Sulphate of magnesia	15.5
Sulphate of lime	7.1
	226.1

Chlorate of magnesia, hydriodate of magnesia, iodide of magnesium, nitrate of magnesia, ammonia-nitrate of magnesia, sulphuret of magnesia, hyposulphite of magnesia, and sulphite of magnesia, it is not thought necessary to describe.

Sulphate of Magnesia is a useful compound obtained chiefly from concentrated sea water, after the extraction of common salt. It is extensively used in medicine, and in the manufacture of carbonate of magnesia. Its crystalline form is four-sided prisms, with two-sided terminations. It is known by the name of Epsom salts, having at one time been obtained from springs at Epsom, in Surrey.

Ex. 64. Beautiful crystals of this salt may be obtained by pouring off the remaining solution from a quantity of crystals just formed, into a flat dish; other crystals will be produced, which must be occasionally turned, and carefully prevented from touching each other. If the solution becomes too weak, the crystals may be put into one rather stronger. Crystals so obtained will be beautifully brilliant, and perfect in their forms, and may be preserved for a long time in well stopped-bottles.

The following compounds are just named in their places: ammonia-sulphate of magnesia, sulphate of potash and magnesia, phosphuret of magnesia, hypophosphite of magnesia, phosphite of magnesia, phosphate of magnesia, bi-phosphate of magnesia, and ammonia-phosphate of magnesia.

Carbonate of magnesia is a white, tasteless, and nearly insoluble powder, and is the magnesia of the shops. When the carbonic acid is expelled from carbonate of magnesia, by exposing it for a considerable time to a red heat in a crucible, it becomes pure, or what is called in the shops calcined magnesia. Carbonate of magnesia is found native, and is called magnesite. Carbonate of magnesia is usually prepared from sulphate of magnesia, by adding carbonated alkali; and large quantities have been obtained from sea water.

Bi-carbonate of magnesia is formed by dissolving the carbonate in excess of carbonic acid.

Borate of magnesia is found native in the duchy of Lunenburg, and may be formed artificially.

MANGANESE exhibits a dull whitish-coloured appearance when newly fractured, but soon oxidizes when exposed to the air, and becomes of a dark colour. It is brittle, very hard, and fuses with great difficulty. Its specific gravity is eight, and its atomic number is twenty-eight. It may be procured by heating the protoxide, mixed with charcoal, to a very intense degree.

Manganese combines in three different proportions with oxygen, according to some authors, and in four or five different proportions according to others. There are three combinations that seem to be well characterized. The first of these, or *protoxide*, is produced by the action of muriatic acid on the common black native oxide of manganese; the chlorine of the muriatic acid is given out, and its hydrogen combines with a proportion of the oxygen of the oxide of manganese to form water, while the metal, having lost a portion of its oxygen, becomes capable of solution, and is dissolved by the remaining muriatic acid, constituting muriate of manganese. Excess of ammonia being added to the solution, a white powder is precipitated, which is *hydrated oxide of manganese*. This powder being dried without exposure to air, it assumes an olive

colour, and is the protoxide of manganese. By long exposure to moist air, the protoxide passes into the state of deutoxide, and finally into that of peroxide.

The *deutoxide* remains in the retort in which peroxide has been heated for the purpose of procuring oxygen. To obtain it pure, superoxalate of potash, water, and peroxide of manganese, in fine powder, must be rubbed together in a mortar; a pink solution results, from which deutoxide of manganese may be precipitated by ammonia.

The *peroxide of manganese* is found native in great abundance, in Devonshire, Somersetshire, Aberdeenshire, and other places. It is usually compact, and of a black colour; but some portions are found crystallized in a radiated form, and in the form of rhomboidal prisms, having a bright grey metallic lustre.

Peroxide of manganese is now a very important article in the arts. It is used for obtaining oxygen for experimental purposes; it is used in pottery and in glass making, to which, when in excess, it gives a purple colour; and it is an important agent in the process of bleaching.

A very curious substance, called *cameleon mineral*, may be prepared by igniting equal parts of nitrate of potash and black oxide of manganese. The watery solution of this substance exhibits several remarkable changes of colour.

Combinations of the protoxide of manganese

are generally soluble in water, and exposure to air occasions such solutions to become brown and turbid. Hydriodic acid does not precipitate these salts from their solution; ferro-prussiate of potash precipitates them white, and hydrosulphuret of ammonia yellow. The alkalies also throw down white precipitates from these solutions.

The combinations of manganese are numerous, but not of such importance as to justify more than the insertion of their names in this work. Chloride of manganese, muriate of manganese, chlorate of manganese, nitrate of manganese, sulphuret of manganese, hyposulphite of manganese, sulphate of manganese, deuto-sulphate of manganese; phosphuret, phosphite, hypophosphite, phosphate, and carbonate of manganese.

IRON is a bluish-white coloured metal, malleable, tenacious, and ductile; it requires a very high degree of temperature for its fusion, and possesses the property of welding, when heated to a white heat; so that several pieces may be united together by the hammer as if they were one. The specific gravity of iron is 7.77. Masses of this metal of considerable size have been found native in different parts of the world, and usually alloyed with nickel, on which account they are considered to have had the same origin as meteoric stones, which always contain a proportion

of that metal. The largest mass of native iron which has been described, was found in Peru, and weighed about fifteen tons. A mass of the same substance, appearing like a large globe of fire, was seen to fall from the atmosphere in Croatia, in the year 1751, and is now in the imperial museum of Vienna. The atomic number of iron is 28.

Iron combines with oxygen in two proportions, forming the protoxide and the peroxide of iron. Iron is one of the most abundantly diffused substances in nature, in various combinations, in clays, sands, mineral waters, animal and vegetable substances; but the most important of these combinations are the oxides, as it is from them that metallic iron is usually obtained. The ore of iron, called clay iron-stone, from which the greatest supplies are obtained, accompanies coal and limestone, both of which are necessary for their reduction; they are first roasted, then broken into fragments, and thrown into conical furnaces from twenty to thirty feet high, with limestone and coke, until the furnaces are full: a powerful blast of air is blown into the furnace below, and the reduced iron passing through the melted earthy matter, to the bottom of the furnace, where a large stone, capable of bearing heat, is placed to receive it. The limestone and the earthy matter of the iron ore fuse into a vitreous substance, which is allowed to run out in a con-

stant stream. The iron obtained by this process is of different qualities, according to the quality of the ore, the fuel, and the limestone. When a sufficient quantity has been prepared in the furnace, it is permitted to run into moulds made in sand to receive it. In the state which it assumes when cold it is called pig iron, and is the same that is used in the founderies for casting in moulds: hence it is called cast iron. To convert cast into malleable iron, it is put into an open furnace, called a refinery, where it is melted in a coke fire with the aid of a powerful blast; the melted metal runs through the coke, leaving much of its impurities behind. It is then cast into plates, which are thrown into water, that they may be more easily broken in pieces. The metal is then placed in the puddling furnace, where it is heated without a blast; it is prevented from melting by the occasional addition of a small quantity of water: in this state it is stirred and moved about for a length of time, until a large proportion of its carbon gradually escapes. When sufficiently prepared in this way, it is rolled up into balls of less than one hundred weight each, and placed under a heavy hammer, moved by machinery, by which its impure or fusible parts are forced out: a very considerable loss of weight is occasioned by this process. The iron is heated again, and beaten or rolled into bars; which, to produce the best iron, are cut

into short lengths by shears worked by machinery, and the same process of heating, hammering, and rolling is several times repeated. The ease and facility with which these important operations are managed at the great iron works, surprise those who have not been accustomed to see them. Thick short bars of iron, of considerable weight, may be seen brought from the furnace, and placed between apertures in rollers, by which the width of the bars is almost instantly reduced, and their length increased. In this way they are made to pass in succession through apertures of different sizes between rollers, until they are brought to the proper size and shape, the whole operation being performed while the bars remain red hot.

When articles of iron are worn out in the uses to which they are applied, the pieces are collected, under the name of scrap iron, which is bound into bundles, heated, and hammered or rolled into bars again.

In the process of converting cast into malleable iron, carbon is the principal, but not the only substance, which is to be got rid of; for it has been found, in analyzing cast iron, that it sometimes contains calcium, often sulphur and phosphorus, and almost always either silex or silicium and oxygen.

By tearing a bar of the best wrought iron asunder, it may be seen that it is composed

of parallel fibres running the whole length of the bar.

It is remarkable that iron deprived of its carbon by the processes alluded to, may again be carbonized, by being heated with charcoal, and is then converted into steel, which differs very much from cast iron. To convert iron into steel, moderate sized bars of pure iron are put into close vessels with layers of charcoal, in furnaces of a peculiar construction, of the reverberatory kind. The heat necessary in this process is very high, not much short of a melting heat, and must be continued for about seven days and nights before the steel is complete: the furnace requires about the same time to cool before the steel is withdrawn. When taken out the steel is covered with blisters, on which account it is called blistered steel. The imperfections occasioned by the blisters are remedied by heating the bars moderately, and submitting them to the tilt hammer, after which the steel is called shear steel.

Cast steel is admirably adapted for some purposes, and is made by fusing blistered steel in close crucibles, with the aid of proper fluxes.

Iron, by being converted into steel, is said to increase in weight from four to twelve ounces per hundred weight.

An excellent variety of steel is known under the name of Indian steel, or Wootz. It appears to be preferable to any other for edge tools.

The superiority of this variety of steel is supposed to depend upon its combination with a small portion of the earths, alumine and silex.

The most important property of steel is, that any required degree of hardness may be imparted to it. When it is heated red hot, and cooled suddenly by being plunged into cold water, it is rendered so hard and brittle as to be unfit for most uses; but this hardness may be reduced by tempering, which is effected by heating the steel to the desired degree, and then cooling it in cold water. A small instrument of steel may be tempered by heating in the flame of a candle, until the required colour is produced, and cooling it by whirling it through the air. The surface of brightened steel undergoes a variety of colours, as the heat to which it is submitted is increased. These changes begin to appear at 430° , which gives a faint yellow colour, the proper temperature for lancets; 450° , a pale straw colour, for razors and surgeons' instruments; 470 , a full yellow, for penknives; 490 , a brown colour, for scissors and chissels for cutting old iron; 510 , a brown with purple spots, for axes and plane irons; 530 , a purple colour, for table knives and large shears; 550 , a bright blue, for swords, watch and other springs; 560 , a full blue, for small fine saws, daggers, &c.; 600 , dark blue, almost

black, gives the softest temper used, fit only for hand and pit saws, which require to be soft, on account of setting and filing the teeth.

The best method of tempering fine edged instruments and tools, is by immersing them in a bath of oil or quicksilver, until they are heated to the required degree by a thermometer.

Protoxide of iron may be obtained by washing and drying in a red heat the precipitate obtained by adding potash to sulphate of iron: it is of a black colour. This combination may also be produced by burning iron in oxygen gas, a beautiful experiment which has been already described under oxygen.

Peroxide of iron may be obtained by boiling the protoxide in nitric acid, precipitating by ammonia, washing the precipitate and drying it at a low red heat; the substance becomes brown and increases in weight: it is the peroxide. These oxides enter into combination with the acids, and form salts that are different from each other. The salts of the protoxide are distinguished by a green colour, are capable of crystallizing, and assume a reddish brown colour when exposed to the air. The combinations of the peroxide are mostly uncrystallizable; they are soluble in alcohol, and are of a brown colour.

The following compounds are not very important: chloride and perchloride of iron; chlorate, muriate, protomuriate, and permuriate of iron, iodide and iodate of iron; protonitrate and pernitrates of iron.

Sulphuret and bi-sulphuret of iron. The first of these compounds is of a black colour, and is called magnetic iron pyrites; it seldom occurs, and contains half the quantity contained in the bi-sulphuret; this last mentioned combination is a very abundant natural production, assuming a great variety of different appearances, and crystallizing in a variety of forms, the chief of which is the cube; it is usually of a brass yellow colour, and is generally known by the names of mundic and iron pyrites. It is useful in the manufacture of sulphate of iron or green vitriol, and in the manufacture of sulphuric acid.

Protosulphate of iron is produced by the union of protoxide of iron with sulphuric acid. It crystallizes in the form of rhomboidal prisms of a green colour, and is known by the name of green vitriol. It may be obtained by dissolving iron filings in dilute sulphuric acid; the solution must be filtered and evaporated, and then suffered to cool and crystallize. This salt is of great use in dying, in ink making, and for a variety of other purposes.

Persulphate of iron is produced when the moist red oxide is dissolved in sulphuric acid.

Phosphuret of iron, protophosphate, and perphosphate of iron are unimportant.

Carburet of iron. Carbon combines with iron to form the substance usually known by the names of blacklead, graphite, or plumbago. It consists of ninety-five parts carbon and five parts iron: it burns with great difficulty, and is considered infusible.

Carbonic acid combines with iron when solutions of carbonate of potash and sulphate of iron are added together, producing a precipitate of a green colour, which is protocarbonate of iron. These substances are also found combined in the natural substance, called spathose iron ore.

Prussian blue is an important colouring substance, into which iron enters as a constituent part. In the process for manufacturing Prussian blue, ferroprussiate or ferrocyanate of potash is first prepared by throwing into an iron pot heated to redness, a mixture of pearlash and animal matter, such as hoofs, horns, or dried blood, in the proportion of about two parts of the alkali to five of the animal matter. While the ingredients are calcining, they require to be actively stirred. The mixture assumes a pasty appearance, and fetid animal vapours effect their escape. The heat and the agitation must be continued as long as the vapours are disengaged. The mass must then be taken out with an iron ladle, and allowed

to cool. When it is quite cold, it must be dissolved in water, and the solution filtered and evaporated; on cooling, crystals of ferropotassium ferrioxalate of potash will be formed. To form Prussian blue, add to one part of these crystals dissolved in water, one part of sulphate of iron, and four parts of alum, both in solution; the precipitate which will be thrown down has not the perfect blue colour at first, but acquires it by being washed with dilute muriatic acid. The use of the alum in this process is, to give a body to the Prussian blue. Prussian blue prepared in this way is void of taste, it is insoluble both in water and alcohol, and it is not affected by dilute muriatic, nitric, or sulphuric acids.

Solution of ferrocyanate of potash precipitates a large proportion of the metals from their solutions of different colours.

Soda, ammonia, lime, magnesia, barytes, and strontian, may be combined with the ferrocyanic acid, by boiling them with Prussian blue.

Borate of iron is not an important combination.

It is not necessary to remark upon the importance of iron, or on the uses to which it is applied, as these are generally known. It appears that iron is of greater importance in the arts of life, than all the other metals put together.

ZINC is a metal rather brighter in its lustre than lead; it is of a bluish white colour. Its atomic number is 34. It is possessed of very

little malleability, but it may be rolled into thin plates, and drawn into wire. It melts with a heat of about 700° of Fahrenheit, and burns soon after it becomes red hot, with a bluish flame, combining rapidly with oxygen, and assuming the state of a white powder, which is called flowers of zinc.

This metal is used for voltaic combinations, and for other purposes in chemistry and the arts, but the chief consumption of this metal is in the manufacture of brass. To obtain the metal for commerce from the ores of zinc, blende, and calamine, they are broken into small pieces and roasted, for the purpose of driving off sulphur from the blende, and carbonic acid from the calamine. The ore is next washed, reduced to powder, and being well mixed with about an eighth part of its weight of pulverized charcoal, the mixture is put into earthen jars, which are placed in furnaces; from every jar an iron tube passes through the floor of the furnace, into water beneath, every other part of the jars being closed. As soon as the jars acquire a red heat, zinc distils through the tube into the water, and is afterwards melted into cakes.

Most of the salts of zinc are capable of being dissolved in water, and their solutions are transparent and free from colour. They are precipitated white by alkalies, and by the soluble phosphates, carbonates, and borates; and yel-

lowish white by ferrocyanate of potash and hydrosulphuret of ammonia. Hydriodic acid does not precipitate them. Their names are as follow: oxide of zinc; chloride and chlorate of zinc; iodide and iodate of zinc; nitrate of zinc; sulphuret, hyposulphite, sulphite, and sulphate of zinc; phosphuret, hypophosphite, phosphite, and phosphate of zinc; carbonate and borate of zinc.

TIN is procured in great abundance from the native combinations of this metal with oxygen, called tin stones, by heating it strongly with carbonaceous substances; it is, when pure, of a white colour resembling silver, but tarnishes by exposure to air. It is softer than zinc, but harder than lead, its specific gravity is 7.291; it is malleable, and admits of being rolled into leaves only one-thousandth part of an inch in thickness; it is not very ductile; it is flexible, bending with a crackling sound. Its atomic number is 58. This metal was known at an early period of the age of the world. It was used by the Egyptians in the time of Moses; Homer was acquainted with it; and it was imported from Cornwall by the Phœnecians and Greeks several centuries before the commencement of the Christian æra.

Tin melts at 440° . It combines with oxygen in two proportions.

Protoxide of tin is precipitated when ammo-

nia is added to protomuriate of tin: its colour is grey.

Peroxide may be obtained by adding nitric acid to the metal. The peroxide is produced in the form of a yellowish powder, which when washed is sufficiently pure; the alkalies dissolve it, and when melted with glass, it forms a white enamel.

Tin combines with chlorine in two proportions, forming chloride and bi-chloride of tin.

Protomuriate of tin results when one part of tin is boiled with two parts of muriatic acid; it throws down a purple precipitate, from infusion of cochineal.

Permuriate of tin is produced by exposing tin to the action of nitro-muriatic acid. There is a tendency in this solution to assume a gelatinous form, to prevent which, the metals should be added in small portions at a time, and each portion should be completely dissolved before another is added. This solution is of great use to dyers, for brightening colours; but chiefly cochineal, with which it produces a beautiful scarlet.

Iodide, iodate, nitrate, and sulphuret of tin are not important in the arts.

Bi-sulphuret of tin, known by the name of aurum musivum, or mosaic gold, is used for imitating bronze, on plaster casts, and for other purposes. To prepare it, twelve ounces of tin must be amalgamated with six ounces of quick-

silver; pulverize the amalgam, and add to it seven ounces of flowers of sulphur, and six ounces of sal ammoniac; apply a sand heat to the mixture in a glass matrass. The heat must not be urged too much, until the fumes abate, and then it must be raised to redness, and kept at that temperature for some time. When the matrass is broken, after it is cold, the aurum musivum will be found at the bottom.

The following compounds are of little importance: hyposulphite, sulphite, and sulphate of tin; hydrosulphuretted oxide of tin; phosphuret, phosphite, and phosphate of tin; carbonate and borate of tin.

Water is capable of dissolving most of the salts of tin, and they are precipitated from these solutions of an orange colour, by hydrosulphuret of ammonia and hydriodic acid, when there is no excess of acid. Salts of tin, containing the protoxide, are precipitated by solutions of gold and corrosive sublimate; but the peroxide is not precipitated by these solutions.

CADMIUM is a metal resembling tin, which is obtained from some of the ores of zinc. Its atomic number is 56. Dr. Wollaston's mode of procuring cadmium from the solution of a salt of zinc, supposed to contain it, is to precipitate all the other metallic substances by iron; the solution is then filtered, and a cylinder of zinc placed in it, by which cadmium, if there is any in the solution,

will be precipitated in a metallic state; and when redissolved in muriatic acid, will exhibit its peculiar characters on the application of proper tests.

This metal is harder and possessed of greater tenacity than tin. It is malleable and ductile: it melts, and is converted into vapour, at a heat below redness. Its specific gravity is nearly eight.

Oxide of cadmium, and the other combinations of this metal, are not as yet applied to useful purposes.

COPPER occurs native in a great variety of forms; it is a metal of extensive use in the arts; it is distinguished by a peculiar reddish colour; it is very malleable and ductile; it possesses a greater degree of tenacity than any other metal, except iron, and it is highly sonorous; its specific gravity is from 8.6 to 8.9, and its atomic number is 64. The melting point of this metal is 4587° of Fahrenheit's scale, corresponding with 27 of Wedgewood's pyrometer, and it burns with a bluish green coloured flame. Copper combines with oxygen in two proportions.

Protoxide of copper is of a red colour; it is found native, and may be artificially produced by mixing metallic copper with peroxide, and digesting the mixture in muriatic acid; potash added to this solution, throws down a hydrated protoxide of an orange colour, which changes to

a red brown colour when dried out of contact of air; it consists of one proportion of copper and one of oxygen.

Peroxide of copper is obtained by adding solution of potash to nitrate of copper; the precipitate must be washed and exposed to a red heat; it is of a black colour, and is composed of one proportion copper and two proportions oxygen.

Copper combines with chlorine in two proportions, forming the protochloride, which consists of one proportion of copper and one of chlorine; and the perchloride, which consists of one proportion copper and two proportions chlorine.

When copper in the state of filings, or thin leaves, is introduced into chlorine, they suddenly unite together with flame, producing both the combinations above named.

Protochloride of copper results when two parts of corrosive sublimate are heated with one of copper filings. It is of an amber colour and translucent. Boyle, who first discovered it, called it resin of copper.

Perchloride of copper may be produced by very slowly evaporating to dryness, at a temperature of about 400° , the deliquescent muriate of copper, which is obtained by dissolving peroxide of copper in muriatic acid. The perchloride is a yellow powder, which, by exposure to air, absorbs moisture, assumes a white and then a green colour, becoming muriate of copper again.

The combinations of copper with muriatic acid and with iodine are not important.

Nitrate of copper is formed when nitric acid, mixed with about three times its bulk of water, is permitted to act upon copper; the bright blue solution obtained, deposits when evaporated, blue prismatic crystals, which are deliquescent and caustic.

Ex. 65. An interesting experiment may be made by putting about one quarter of an ounce of nitrate of copper coarsely bruised, upon a piece of tinfoil six inches square; moisten the nitrate a little by sprinkling with water, and quickly fold the tinfoil all round the nitrate, so as to make it as close as possible. Sometimes a small quantity of tow is put upon the nitrate before folding the tinfoil. The whole will soon be very much heated, portions of the dissolved nitrate will begin to ooze through, and streams of nitrous gas will be forced out, attended by sparks of ignited tin and small jets of fire. The striking effect produced in this process depends upon the decomposition of the nitric acid, of the nitrate of copper, and a portion of its oxygen uniting rapidly with the tin.

Ex. 66. Another pleasing experiment may be performed with nitrate of copper. Dissolve in a wine glass nearly full of water, a very small quantity of nitrate of copper, scarcely enough to give a perceptible tinge of colour to the water, and then

add liquid ammonia, by which an exceedingly beautiful blue colour will be produced, which will disappear on the addition of a few drops of muriatic, nitric, or sulphuric acid.

Brunswick green is a compound produced by submitting plates of copper to the continued action of solution of muriate of ammonia.

Copper combines with sulphur in two proportions, forming sulphuret and bi-sulphuret. The first is a black brittle substance, which exists native, and which may be obtained artificially by heating a mixture of sulphur and copper filings. As soon as the sulphur melts a rapid action takes place, hydrogen is set free, the copper becomes red hot, and is converted into sulphuret of copper, which consists of one proportion copper and one sulphur.

Bi-sulphuret of copper is known by the name of copper pyrites. It has a brilliant metallic lustre, and a golden yellow colour. It is composed of one proportion copper and two proportions sulphur. This is the most important native combination of copper, as it is the source of most of the metallic copper which is manufactured. The primitive crystalline form of this substance is the regular tetrahedron, but it is found of a variety of forms. It abounds in the Isle of Anglesea and in Cornwall. A large proportion of the ore of this metal is sent to the neighbourhood of Swansea, to be reduced to the metallic state.

Hyposulphite and sulphite of copper are unimportant.

Persulphate of copper is known by the name of blue vitriol. It crystallises under favourable circumstances, in very large crystals of a rhomboidal prismatic shape, and of a beautiful blue colour. These crystals may be obtained from the solution of peroxide of copper in sulphuric acid. This compound is produced upon a large scale by exposure of roasted sulphuret of copper to air and moisture.

Ex. 67. A piece of polished iron plunged into a solution of persulphate of copper is instantly coated with copper, which is thus explained: the iron having a stronger attraction for the acid of the sulphate of copper, attracts a portion of it, and the copper that is deprived of its acid is precipitated upon the surface of the iron.

It will be sufficient merely to name the following compounds: sulphate of copper and potash; phosphuret, hypophosphite, and phosphite of copper.

Carbonate of copper is formed upon the surface of copper that is exposed to damp air. It may be prepared by adding carbonate of potash to sulphate of copper: the precipitate is green, and insoluble in water. Its colour may be much improved by washing it in different portions of boiling water. Refiners' verditer is a preparation of this kind.

A good common kind of verditer may be made as follows : add lime to solution of nitrate of copper, wash the precipitate, and place it upon a strainer until it is nearly dry ; it will have a greenish hue ; then mix it well with eight or ten per cent. of lime, which will give it a blue colour : it must be carefully dried.

Carbonate of copper occurs native, of a green and blue colour ; the variety called malachite, is veined with different shades of green, and is, when cut and polished, extremely beautiful. A less compact variety is known by the name of mountain green. The blue variety is called mountain blue.

Borate and ferrocyanate of copper are unimportant.

The alloys of copper are numerous and important. Gold used for coining is alloyed with one part in twelve of copper. Jewellers' gold is alloyed with different proportions of copper. It is also combined with silver in small quantity to render it fit for coin and plate. Perhaps the most extensively useful alloy of this metal is that which it forms with zinc, called brass. There would be great difficulty in uniting these metals in a direct way by fusing them together, because the zinc would volatilize at a temperature lower than that which is required to melt the copper ; but it is accomplished by a process called cementa-

tion. The copper is prepared by melting it, and pouring it through holes perforated in an iron plate into water. The ore of zinc, called calamine, having been roasted and pulverized, is mixed with the finely divided copper and with a portion of charcoal. The mixture is then submitted to the heat of a wind furnace, the zinc of the calamine is revived, and combines with the copper, forming brass. When the process has been continued sufficiently long, the heat is suddenly raised, by which the brass is melted, and falls to the lowest part of the crucible. Another method recommended is, to mix the powdered calamine with an equal quantity of charcoal and a portion of clay, and ram it into a melting vessel; copper, in the proportion of two-thirds the weight of the calamine, must be put upon the top, and be covered with charcoal; when heat is applied the volatilized zinc ascends, and converts the copper into brass.

Other alloys of copper and zinc are called by different names, in proportion to the quantity of copper and other ingredients which they contain. Of this kind are Dutch gold, tombac, pinchbeck, and prince Rupert's metal. Tutenag is said to be a similar alloy with a little iron. Six parts of copper, two of tin, and one of arsenic, melted together, form speculum metal. Bell metal is an alloy of three parts of copper and one of tin:

small bells require the addition of a little zinc. Bronze is an alloy of one hundred parts of copper with ten or twelve of tin.

The salts of copper are mostly soluble in water, and the solutions are blue or green; clean iron plunged into such a solution attracts acid and precipitates metallic copper; hydrosulphuret of ammonia throws down a black precipitate; ferrocyanate of potash occasions a brown colour; and ammonia produces a beautiful blue when added in excess.

Many of the compounds of copper are active and virulent poisons, when admitted into the stomach in the quantity of a few grains only. It is supposed that the poison is absorbed, and acts upon the brain and nerves through the circulation. The symptoms by which death occasioned in this way is preceded, are convulsive movements, tetanus, and insensibility of the lower extremities.

The most powerful and efficacious antidote to this poison is sugar, although the manner of its action is not well understood. A large quantity, amounting to four French drachms, of solution of oxide of copper in acetic acid, was introduced into the stomach of a dog by M. Duval; in a few minutes afterwards he injected four ounces of strong syrup, in half an hour he injected four ounces more; the animal trembled a little, and was slightly convulsed; in half an hour more

he introduced a third quantity of four ounces, after which the animal seemed quite easy; it fell asleep, and awoke quite well. M. Orfila proved repeatedly that a dose of verdigris capable of killing a dog in the space of an hour or two, might, when mixed with a considerable quantity of sugar, be taken into the stomach without injury; and he relates many instances of persons who had swallowed poisonous doses of acetate of copper, who were saved by large doses of sugar.

LEAD is a bluish-white, soft, and flexible metal, of the specific gravity of 11.35: its melting point is 612° . When melted and exposed to air it oxidizes, and is converted into a greyish powder, which is a mixture of the protoxide with metallic lead. The protoxide, when pure, is of a yellow colour, and may be obtained by adding solution of potash to a solution of nitrate of lead; the precipitate washed and dried will be the protoxide: it is called massicot in commerce. The atomic number of lead being 104, this combination of lead and oxygen, composed of one proportion of each, is indicated by the number 112. It is obtained on a large scale in a vitrefied state; it is then called litharge. Massicot exposed to the flame of a reverberatory furnace for forty-eight hours, assumes a beautiful red colour, and is converted into red lead or minium, which is supposed to be a compound of the protoxide and peroxide

of lead. The peroxide is obtained by digesting nitric acid on minium; a large proportion will be dissolved, and a brown insoluble powder will remain, which is the peroxide. It is composed of one proportion of lead, and two proportions of oxygen.

Chloride of lead is produced by exposing thin pieces of lead to the action of chlorine, aided by heat, or by submitting nitrate of lead to the action of muriatic acid. When the substance formed is dry, it has a horn-like appearance, on which account it used to be called *plumbum corneum*.

Chlorate, iodide, iodate, and nitrate of lead are not important.

Sulphuret of lead may easily be artificially formed. It abounds as a natural product, and is of vast importance, as the source of metallic lead: it is usually called galena. Its colour and appearance very much resemble lead, but it has more lustre: its primitive crystalline form is the cube. To reduce this ore to metallic lead, it is picked, broken, washed, roasted in a reverberatory furnace, to expel the sulphur, and then melted. It is said that 48,000 tons of this metal are obtained from the British mines annually.

Hyposulphite, sulphite, sulphate, and hydrosulphuretted oxide of lead; phosphuret, hypophosphite, phosphite, and phosphate of lead, need not be described.

Carbonate of lead may be prepared by adding

solution of carbonate of potash or soda to solution of nitrate of lead. The substance known by the names of ceruse and white lead, and extensively used as a white paint, is prepared upon a large scale by submitting sheet lead to the action of the vapour of vinegar.

The lead is rolled up into a spiral form, leaving a small space between each coil; the roll is then put into an earthen pot, containing some vinegar. A number of pots being prepared in this way, they are covered over, put into a sand bath, and gently heated for a long time. The white substance formed by this process comes off in flakes when the lead is uncoiled; it is then rolled up, and the process is renewed until all the lead is corroded. Ceruse dissolved in the acetic acid forms sugar of lead, which, like many other preparations of lead, is highly poisonous. The best antidote to poison of this kind is solution of Epsom or Glauber salt, taken in large quantities. The sulphuric acid of either of these salts combines with the lead of the poisonous acetate, and converts it into a harmless sulphate of lead.

The protoxide is the base of the salts of lead; those that dissolve in water yield colourless solutions of a sweetish astringent taste. Metallic lead may be obtained from them all, by submitting them on charcoal to the flame of the blowpipe. Ferro-prussiate of potash and gallic acid throw down white sulphuretted hydrogen,

and hydrosulphuret of potash black precipitates: from the solutions of these salts hydriodate of potash occasions a yellow precipitate.

The most important alloys of lead are those which it forms with tin and antimony. Various proportions of lead and tin are used for making pewter: the common kind has about one-fifth part lead. Two parts of lead and one of tin, and sometimes equal parts of lead and tin, constitute plumbers' solder. By melting eight parts bismuth, five lead, and three tin, a metal is produced, so fusible that it melts with less heat than is required to make water boil.

Lead, combined with about a sixth part of sulphuret of antimony, forms the best metal for printers' types and stereotype plates.

In addition to the preparations of lead already mentioned, may now be noticed its combination with the chromic acid, which produces that beautiful yellow colouring substance, chromate of lead. Lead is also an important ingredient in the glazing of pottery, and in the manufacture of glass.

ANTIMONY occurs native, but it is found most abundantly in combination with sulphur. The most usual form in which this substance is found is that of a radiated mass of needle-shaped crystals, of a grey colour, and metallic lustre. To reduce the sulphuret to pure antimony, it is reduced to powder, three parts of which must be

mixed with two of crude tartar; the mixture must then be thrown, by spoonfuls at a time, into a red hot crucible; when the mass is heated to redness the antimony will be found at the bottom of the crucible nearly pure. If it is required perfectly pure, the quantity obtained by the process just described must be dissolved in nitro-muriatic acid; the addition of a large quantity of water will throw down a white powder, which being again exposed to fire, with twice its weight of tartar, pure antimony will remain in the crucible. It is a white, brittle, crystalline metal, of the specific gravity of 6.8, its atomic number being 44. Antimony melts at 800° , and is volatilized by an intense heat; exposed to a current of oxygen on ignited charcoal it burns with brilliant appearances. There are two oxides of antimony of some importance in pharmacy; but as a description of these and other combinations of antimony would not be interesting or useful to readers in general, they are omitted.

The utility of antimony in the composition of metal for printers' types has already been adverted to; it also forms a part of other useful compounds: the finest pewter is composed of twelve parts tin, one part antimony, and a very small quantity of copper. A metal, which answers well for teapots, is a compound of two parts copper, two parts bismuth, eight parts antimony, and one hundred parts tin.

BISMUTH is useful chiefly in a state of combination with other metals. It is a white metal, with a slightly reddish hue: its specific gravity is 9.85; it occurs native, and in various combinations. Being of little use in the arts, excepting as it enters into the composition of soft solder and fusible metal, it is inconsistent with the plan of this work to dwell upon it or its compounds.

COBALT is found in combination with oxygen, sulphur, iron, arsenic, and nickel. It is a brittle metal, of a reddish grey colour, of the specific gravity 7.7. Its atomic number is 26. It fuses with great difficulty, and is slightly magnetic. It unites with two proportions of oxygen, and enters into a variety of other combinations. Zaffre, the preparation of cobalt best known in commerce, is produced by calcining its ores, to expel the sulphur and arsenic: an impure oxide of cobalt remains, with which pulverized flints, in the proportion of twice the weight of the cobalt, are mixed. Zaffre is melted with glass, to form smalt, or azure blue; the blue glass obtained is thrown into water while hot, and then finely pulverized.

The chief use of cobalt consists in its application as a colouring matter to earthenware and glass. Oxide of cobalt is so powerful in imparting colour, that one grain of it gives a full blue to 240 grains of glass.

Muriate of cobalt may be obtained by digesting the oxide in muriatic acid. The solution obtained when a little diluted is of a pink colour, and forms a sympathetic ink, as it is called. The writing with it is invisible until it is heated; it then appears in beautiful green characters, which disappear again when the paper cools. If the paper is too much heated, the characters do not quite disappear afterwards.

Phosphate of cobalt results from the addition of phosphate of soda to muriate of cobalt: its colour is lilac, and it is insoluble. A mixture of this heated with eight parts of gelatinous alumina, produces a beautiful blue colouring matter, which has been recommended as a substitute for ultramarine.

URANIUM is a brittle grey-coloured metal, which may be obtained from the native sulphuret of uranium. The native hydrated oxide, called uranite, is a beautiful green-coloured mineral; but neither the pure metal nor its combinations are important in the arts. The salts of uranium are of a yellow colour. Ferrocyanate of potash throws down a brown precipitate from their solutions.

TITANIUM. This metal is found in combination with oxygen in several mineral substances. It is exceedingly difficult to obtain, and it has not been applied to any important use. Its solutions are without colour; alkalies added to

them occasion white precipitates, ferrocyanate of potash a green, and infusion of galls a red precipitate.

CERIUM has been described as a hard brittle metal. It has not been obtained pure in any considerable quantity. It exists in a state of combination with oxygen, in the minerals called cerite and allanite: there are two oxides of this metal. Ferrocyanate of potash occasions white precipitates when added to their solutions.

TELLURIUM is a brittle metal of a bright grey colour, which is easily melted and volatilized; it is obtained in Transilvania and Siberia, from ores which contain gold: its specific gravity is 6.1. Tellurium enters into various compounds which have not yet been applied to the arts.

SELENIUM has a bright metallic lustre and a grey colour; it melts and volatilizes easily; it combines with the other metals, and forms red compounds with the alkalies.

ARSENIC is a bluish-white coloured metal, which tarnishes rapidly, first assuming a yellowish, and then a black colour, by exposure to air; its specific gravity is nearly six; it is very brittle, and very volatile, so that it may be distilled in close vessels at 360° . The smell of its vapour resembles that of garlic; it burns when heated in air, and is converted into oxide of arsenic. There are two compounds of arsenic and oxygen, called arsenious acid and arsenic acid, as they are soluble

in water, sour to the taste, and are capable of combining with other metallic substances. The first of these is the most common; it is known by the name of white arsenic, and is the deadly poison, the effects of which have so often been the subject of investigation. This substance is chiefly obtained for commerce, by the roasting of the ores of cobalt, with which arsenic is combined. Arsenious acid is a brittle white substance, semi-transparent, and when broken presenting a vitreous fracture; its specific gravity is 3.7. When thrown upon hot coals it produces white flames, attended by the characteristic smell of this substance when heated, which is like that of garlic. This substance is so virulently poisonous, that it may produce fatal effects when mingled in such small quantity in liquids, as not to be sensible to the taste. One thousand parts of boiling water are capable of dissolving seventy-two parts of it, thirty of which remain dissolved when the water is cold; but when put into cold water at first, only one-third part of the last mentioned quantity is dissolved. This solution reddens litmus paper, and renders green the syrup of violets; lime water throws down a fine white powder, which is arsenite of lime, and a golden yellow. Sulphuret of arsenic is produced by adding sulphuretted hydrogen gas, or hydrosulphuretted water to the solution of arsenious acid.

Several different methods are employed for the purpose of ascertaining the presence of arsenic, when there is reason to suspect that it has been used as a poison. In such a case, when the fluid expelled from the stomach by vomiting, or extracted by the stomach pump, is to be examined, care should first be taken to discover if any white powder subsides from the fluid when it is diluted with water; if such a precipitate should appear, it must be carefully collected, and submitted to examination. Being mixed with double its bulk of black flux, and introduced into a small glass tube, close at one end, the heat of a spirit lamp should be gradually applied, until the tube becomes red hot. Should a proportion of the matter acted upon be arsenic, its peculiar garlic-like odour will be produced by the fumes proceeding from the heated tube; and a crust of steel-coloured metallic arsenic will form upon the cool part of the tube: this substance may be submitted to the action of the various tests with which it produces characteristic appearances. The same process may be used for the examination of suspicious particles obtained in any other way from the body, or found in the stomach after death.

If no solid particles should appear in the fluid, they may be evaporated to dryness with a gentle heat, and the residuum operated upon in the same way.

There are so many circumstances that interfere

to modify, and render erroneous, indications afforded by the actions of tests, that such indications cannot be so confidently relied upon as the results of the foregoing process; at the same time they are deserving of attention. The best of these tests is nitrate of silver. A small quantity of liquid ammonia being added, on the end of a glass rod, to a portion of the liquid supposed to contain arsenic, if another glass rod, wet with a solution of pure nitrate of silver, be also immersed in the liquid, and brought near to the other rod, a yellowish coloured spot will begin to appear, which, after the introduction of a few more minute quantities of the nitrate on the end of the rod, will extend and become bright yellow. If muriate of soda be present in the solution, a white curdy precipitate of muriate of silver will also be produced. A portion of the yellow nitrate of arsenic obtained, being put upon a piece of burning coal, it will emit the peculiar odour of arsenic.

There is no effectual antidote for this poison when taken into the stomach; the only hope of safety being in the sudden and successful evacuation of the poisonous particles; the process being aided by copious draughts of mucilaginous liquids, and, if possible, by water containing sulphuretted hydrogen.

The compounds of the arsenious acid are numerous, but not of such importance as to require detail in this place. Scheele's green, which is a

useful colouring substance, is prepared by mixing solutions of arsenite of potash and sulphate of copper: the precipitate, when washed and dried, is the substance alluded to.

Arsenic acid contains a larger quantity of oxygen, and is obtained by distillation from the following mixture: eight parts of arsenious acid, four parts of muriatic acid, and twenty-four parts of nitric acid. Towards the conclusion of the operation, the bottom of the retort should be raised to a red heat. This acid may also be obtained by submitting to distillation, nitric acid mixed with some finely divided metallic arsenic.

The arsenic acid enters into a variety of combinations, but they are not of much importance in the arts, with the exception of its combinations with sulphur, orpiment, and realgar, which are used as colouring substances. Arsenic itself is useful in imparting a white colour to many metallic alloys, and it is used in the manufacture of glass.

MOLYBDENUM has not been obtained in any considerable quantity. By making a paste with oil and molybdic acid, and exposing the paste to intense heat, imbedded in charcoal, grey, brittle, and infusible globules of the metal are obtained: its specific gravity is said to be about eight. This metal is gradually converted by heat into a white oxide, which sublimes. Molybdenum may also

be obtained from the sulphuret, which is the most commonly occurring compound of this metal.

Molybdenum combines with oxygen in three proportions; the black oxide contains one proportion of oxygen; the blue oxide, which is molybdous acid, contains two proportions; and the white, which is molybdic acid, contains three proportions of oxygen: the last named is the most important of these.

Molybdic acid may be obtained by roasting the native sulphuret, and afterwards dissolving it in water of ammonia; nitric acid added to the solution, occasions a precipitate of molybdic acid, in the form of fine white scales, which change to a yellow colour, when melted or sublimed. It converts vegetable blues into red, but has not a sour taste. When dissolved in hot sulphuric acid, it forms a colourless solution, but as the solution cools, it acquires a beautiful blue colour, the intensity of which is increased by the addition of soda. This acid and its combinations have not yet been applied to the arts.

CHROMIUM is a very brittle metal of a greyish white colour; as usually obtained, it is a porous mass of agglutinated grains, and sometimes it is obtained in the form of needle shaped crystals, crossing each other in all directions: its specific gravity is 5.9. Chromium combines with oxygen in three proportions. When exposed to heat and

air, it is converted into a green *protoxide*, which is soluble in acids: this substance has been found native, and is the colouring principle of the emerald.

Deutoxide of chromium is obtained by exposing nitrate of chromium to a red heat; it is of a brown colour, and insoluble in acids.

Peroxide of chromium, or chromic acid, may be obtained from the chromate of iron, which must be pulverised, mixed with half its weight of nitrate of potash, and submitted to a red heat in a crucible for about two hours; the contents of the crucible, when cold, must be dissolved in water, and nitric acid added to neutralize the excess of potash, the solution will then contain nitrate and chromate of potash; on the addition of nitrate of mercury to this solution, a red powder is precipitated, which is chromate of mercury. This compound may be decomposed by the application of a moderate heat, and chromic acid will remain; it has a sour metallic taste, and a red colour, and is the colouring principle of the ruby.

Some of the compounds into which the chromic acid enters have been found useful in chemical research: the green oxide of chromium is used in enamel and porcelain painting, and the chromate of lead, which is formed artificially, affords a beautiful rich and durable yellow colour.

TUNGSTEN has never been obtained in considerable masses, but in sufficient quantities to

prove that it is almost of an iron colour, hard, brittle, very difficult of fusion, and of the specific gravity of 17.22. There are two combinations of this metal with oxygen; the brown oxide or protoxide, and the yellow peroxide or tungstic acid. The first is formed by passing hydrogen over tungstic acid, in a red hot glass tube; it is of a flea brown colour; and when heated in the air, it takes fire and burns, passing into tungstic acid.

Tungstic acid is usually obtained from the mineral called wolfram. The mineral is first pulverised and mixed in a matrass, with five or six times its weight of muriatic acid, for half an hour. The oxides of iron and manganese in the mineral are dissolved, and the tungstic acid is precipitated in the form of a yellow powder, which must be well washed with water, and when dry, it must be dissolved, with the aid of heat, in an excess of liquid ammonia. The liquid being filtered, it must be evaporated to dryness; the mass obtained being ignited, the ammonia flies off, and pure tungstic acid remains.

This acid is destitute of taste, and has no action on vegetable colours. It enters into a variety of combinations, which, being unimportant in the arts, are not described.

COLUMBIUM has been obtained in a metallic state by the Swedish chemist, Berzelius; and, according to him, it is hard and brittle, of an iron colour, and combines at a red heat with

oxygen, forming a whitish coloured oxide. This metal and its combinations are unimportant in regard to the arts.

NICKEL is a magnetic metal, between silver and tin in colour, very hard, but malleable, and difficult of fusion; it is very little affected by being heated in contact with air. It occurs native in combination with arsenic, and arsenic acid. It is also found in combination with sulphur, and other impurities. This compound is roasted to expel the sulphur and arsenic; it is then mixed with two parts of black flux, in a crucible, and covered over with muriate of soda, and heated intensely in a furnace; but the metal obtained by this process requires farther purification. It should be dissolved in nitric acid, and evaporated to dryness three or four times successively; the residuum must then be dissolved in ammonia free from carbonic acid; evaporate again to dryness, mix the mass with two or three parts of black flux, and expose the mixture to an intense heat in a crucible for at least half an hour. This is evidently a tedious and troublesome process; there are others which may, perhaps, be a little easier, but all are sufficiently difficult.

Nickel combines with oxygen in two proportions.

Protoxide of nickel may be obtained by adding a solution of potash to a solution of nitrate or

sulphate of nickel, the protoxide will be precipitated; it is of a grey colour, and readily dissolves in ammonia, forming a sapphire blue solution.

Peroxide of nickel was obtained by Thenard, by passing chlorine through the protoxide diffused in water, in the form of a black powder.

The other combinations of nickel are numerous, but they are not sufficiently important to require particular description. The solutions of salts of this metal afford a beautiful green colour. From these solutions, ammonia throws down a green precipitate; hydriodate of potash a yellow green, and ferrocyanite of potash a pale grey or greenish white precipitate.

One of the most remarkable circumstances connected with nickel is, that it invariably forms a part of those masses which have fallen upon the surface of our earth in various parts, and which are known by the name of meteoric stones. The proportion of nickel in combination with the iron contained in these stones varies from three to ten per cent. Various attempts have been made to combine nickel with other metals for useful purposes, which have in some instances been attended with success.

MERCURY. The most distinguishing characteristic of this metal is its fusibility, having no tendency to assume a solid state, until it is cooled to the thirty-ninth degree below zero of Fahren-

heit's scale; it boils and is converted into vapour at 656° ; heated a little above this it volatilizes rapidly; when pure, it may be entirely converted into vapour: its specific gravity is 13.5, and its atomic number 200. It occurs native in small globules, but the greatest quantity is found in combination with sulphur, in the mineral called cinnabar; from which the metal is obtained by distillation with iron filings or quick-lime. Mercury combines with oxygen in two proportions.

Protoxide of mercury may be obtained by agitating mercury for a considerable length of time in contact with oxygen, or by pouring hot lime-water upon chloride of mercury, and agitating the mixture: it is a tasteless and insoluble black powder.

Peroxide of mercury is formed when the metal is for a length of time exposed, nearly at a boiling heat, in contact with air. It is of a red colour, has a very acrid and metallic taste, and is highly poisonous.

Chlorine combines with mercury in two proportions, forming the protochloride or calomel, and the perchloride or corrosive sublimate.

Calomel is usually prepared by triturating four parts of corrosive sublimate with three parts of quicksilver as long as any globules appear; the product being submitted to heat, calomel sublimes. The greyish-white cake thus obtained is afterwards reduced to a fine powder, and washed

with large quantities of hot distilled water. It is sometimes obtained by adding solutions of protonitrate of mercury and common salt together: calomel is precipitated.

Mercury being heated in chlorine gas it takes fire and burns with a pale red flame, and a white volatile substance is produced, which is the perchloride, or corrosive sublimate. It may be procured by a variety of other processes.

Both the oxides of mercury are dissolved by the chloric acid, forming protochlorate and perchlorate of mercury.

Mercury combines with different proportions of iodine, forming a yellow protiodide and a red periodide.

Nitric acid unites with mercury, producing two compounds, the protonitrate and pernitrates.

Mercury and sulphur combine, forming the sulphuret, which is a black powder; and the bisulphuret, or cinnabar, which is used as a pigment, and is known by the name of vermillion. It is prepared in the following manner: the black sulphuret of mercury is put into earthen pots, and submitted to a red heat: cinnabar is sublimed.

The other combinations of mercury are numerous, but not important in the arts.

A fulminating preparation of mercury is thus prepared: add to an ounce and a half by measure of nitric acid, one hundred grains of mercury, and apply heat until the mercury is dissolved; when

the solution is cold, mix it with two ounces by measure of alcohol, in a glass vessel, and excite effervescence by the application of heat; a white vapour will then appear, undulating on the surface, and a powder will be gradually precipitated, which being well washed, and cautiously dried by gentle heat, detonates by slight friction on the application of heat, or by percussion.

Mercury is of great use for a variety of purposes; for purifying the precious metals, for filling thermometer and barometer tubes, in the preparation of medicines, in the manufacture of looking glasses, and in forming various amalgams with the metals.

The salts of mercury are characterized by the following properties: they are volatilized by a dull red heat; they are precipitated white by ferro-prussiate of potash, and the proto salts are precipitated of the same colour by muriate of soda. Sulphuretted hydrogen throws down a black precipitate, gallic acid an orange yellow, and a plate of copper precipitates metallic quicksilver.

OSMIUM is a metal of a dark grey colour, infusible, insoluble in the acids, but soluble in solution of potash; it oxidizes readily when heated in air, and its oxide has a very pungent and peculiar smell; tincture of galls produces a blue colour when added to a solution of this oxide.

This metal is obtained from the ore of platinum, by digesting it in muriatic acid; a black powder

remains undissolved, which when it is fused with potash furnishes a yellow alkaline solution of oxide of osmium. Having saturated the alkali in this solution with sulphuric acid, distil the mixture to obtain a colourless solution of the oxide, which will pass into the receiver. By agitating some mercury with this solution it becomes an amalgam, the mercury of which is volatilized by distillation, and osmium remains in a pure state.

IRIDIUM is also obtained from the black powder which remains after digesting the ore of platinum in muriatic acid; the iridium not being soluble in potash remains after the osmium is dissolved. By digesting this last remaining powder in muriatic acid, a solution of oxide of iridium is obtained, which undergoes changes of colour from blue to olive green and red. After evaporating the muriatic solution to dryness, the mass remaining must be redissolved, and the solution concentrated by evaporation; crystals of muriate of iridium, of an octahedral form, are deposited. Metallic iridium may be obtained by heating these crystals intensely, or by immersing a plate of zinc in the solution above named. The specific gravity of this metal is about eighteen. It is of a whitish colour, and very difficult of fusion.

RHODIUM is another metal found in the ore of platinum, from which it may be separated by digesting the ore in a small quantity of nitro-

muriatic acid; add to the saturated solution, after filtering it, a solution of sal ammoniac, by which the platinum will be precipitated: a plate of zinc immersed in the clear remaining solution will be coated with a black powder, which must be digested in dilute nitric acid, washed, and then digested in dilute nitromuriatic acid, with the addition of a little common salt; the whole must be evaporated to dryness, and the remaining mass repeatedly washed with alcohol; a substance of a deep red colour remains, which, being dissolved in water, a plate of zinc precipitates a black powder from the solution; which, being mixed with borax, and submitted to a strong heat, metallic rhodium is obtained. It is white, and has considerable lustre; it is very difficult of fusion, and its specific gravity is 10.6.

Some of the alloys of this with other metals have been examined; that with steel is most approved, but the scarcity of the metal prevents its application.

PALLADIUM, as well as the three last-mentioned metals, has been obtained from the ore of platinum. It is hard, malleable, ductile, of a dull white colour, and is more fusible than the other metals found with it. The nitromuriatic solution of the ore being neutralized by soda, and the platinum precipitated by ammonia, filter the solution, and add to it solution of cyanuret of mercury; a flocculent yellow precipitate will be

thrown down, from which metallic palladium may be obtained by the application of heat. The specific gravity of this metal is about eleven. It is easily dissolved by nitromuriatic acid, affording a fine red solution. Boiled with sulphuric acid, it gives a blue, and with muriatic acid a red colour. Alkalies added to these solutions occasion orange-coloured, ferrocyanite of potash olive green, and sulphuretted hydrogen dark brown precipitates.

SILVER is distinguished by a brilliant and pure white colour; it is exceedingly malleable and ductile. It admits of being hammered into leaves only one hundred and sixty thousandth part of an inch thick; and it may be drawn into wire finer than a human hair. Silver occurs native in considerable quantities, and it is found in very numerous combinations. It may be procured in a perfectly pure state by dissolving the standard silver of commerce in pure nitric acid, diluted with its own bulk of water: the immersion of a clean copper plate into such a solution will occasion a precipitate of metallic silver, which may be collected, washed with ammonia, afterwards with water, and then fused. Another way of obtaining it is, to add common salt to the solution above described; a precipitate will be thrown down, which must be washed and dried, and then melted with its own weight of carbonate of potash: pure silver will result. Its atomic number is 110.

Oxide of silver. It is probable that silver combines with oxygen in two proportions; but one only of these compounds, that which has the largest proportion of oxygen, is well known. It may be procured by mixing solution of nitrate of silver and lime water; the precipitate, when washed, will be of a dark olive colour, without taste, insoluble in water, and easily reduced to the metallic state by heat.

Fulminating silver is composed of oxide of silver, and ammonia; it may be prepared by adding ammonia, perfectly free from carbonic acid, to pure oxide of silver; the resulting black powder is the fulminating compound, which sometimes explodes before it is dry; when quite dry the least heat or friction occasions it to explode with a loud noise. It is a dangerous substance, and cannot safely be made in large quantities.

Chloride of silver results when common salt is added to solution of nitrate of silver; the precipitate is at first white, but changes to brown and black by exposure to light. When this substance, in a dry state, is submitted to a low red heat, it melts; and when cold, forms the substance called horn silver.

Iodide and iodate of silver are unimportant.

Nitrate of silver is readily produced by submitting silver to the action of nitric acid, diluted with about three times its bulk of water. When the nitric acid and the silver are pure, the solution

is colourless. It is a caustic, and produces a deep yellow stain when applied to animal substances; this stain gradually assumes a black colour, and is indelible. The solution, when sufficiently saturated, deposits crystals of a white colour, soluble in their own weight of water. These crystals, melted in silver crucibles, and cast in moulds, form lunar caustic.

Nitrate of silver is easily decomposed. It detonates when a few grains of it are mixed with a little sulphur, and struck with a hammer upon an anvil; the explosion is more violent when a small quantity of phosphorus is used instead of sulphur: the metal is reduced with deflagration when the nitrate is heated with charcoal. A stick of phosphorus immersed in a solution of nitrate of silver attracts the metal, and is soon covered with beautiful arborescent crystals. Silver is also precipitated in a brilliant metallic form, by introducing a plate of copper into a solution of the nitrate.

Silk dipped into a solution of nitrate of silver, and afterwards exposed in a moist state to a current of hydrogen gas, will afterwards, when exposed to light, be covered with a coating of reduced silver.

Nitrate of silver is exceedingly useful as a reagent in chemical researches, on account of its strong affinity for chlorine and muriatic acid. It is used as the principal ingredient in liquids for changing the colour of hair, and as marking ink.

Nitrite of silver, sulphuret and hyposulphite of silver, hyposulphite of potash and silver, sulphite and sulphate of silver, and numerous other compounds into which it enters, are unimportant in the arts.

The salts of silver which are soluble afford metallic silver when a plate of copper is immersed in their solutions; and muriatic acid throws down a white precipitate from these solutions, which blackens when exposed to light.

The most useful alloy of silver is that which it forms with copper, a small proportion of which renders it considerably harder, and fitter for plate and coin. A pound troy of standard silver has eighteen pennyweights of copper.

Plating is the art of covering the surfaces of other metals with silver; copper is mostly used for this purpose. In the superior kind of plating, a thin plate of silver is applied to the surface of the copper, but an amalgam, or rather preparation of silver, is used for common and inferior plating; the following is a preparation of this kind. Two drams of each, tartar and common salt, half a drachm of alum, and fifteen or twenty grains of silver precipitated from nitric acid by copper, must be well mixed together, a portion of silver attaches to the surface of copper which is well rubbed with this powder, it may afterwards be polished with leather.

Thermometer scales and clock-dials, which are

formed of brass, and made very clean, are silvered by being rubbed while wet with a mixture of chalk pearlash and chloride of silver.

GOLD is a beautiful deep yellow coloured metal, which is unalterable by exposure to air, or to the heat of a furnace. Its melting point is a bright red heat, at which temperature its surface assumes a brilliant green colour. It is so malleable, that the gold leaf of commerce is only the two hundred and eighty-two thousandth part of an inch thick, and so ductile that the wire used by lacemakers, and which is drawn from a gilded ingot of silver, is known to have a covering of gold only one-twelfth part as thick as gold leaf, and yet no defects in this fine covering can be discovered by a microscope. The specific gravity of this metal is 19.3, and its atomic number 200. It is found native in veins in primitive districts, and also in grains in alluvial soils, and in the beds of rivers in Europe, Africa, and America. It is readily dissolved in the mixture of nitric and muriatic acids, which is known by the names of nitro-muriatic acid and aqua regia; it is also soluble in aqueous chlorine. Solution of gold gives a deep and permanent purple to animal substances.

Oxide of gold is precipitated when solution of a fixed alkali is added to solution of nitro-muriate of gold; it is soluble in the nitric, muriatic, and sulphuric acids, but separates from them by evaporation or long standing.

The precipitate thrown down by ammonia from a solution of gold, is known as fulminating gold. It should be made in small quantities, and dried in the open air, as it is a very explosive and dangerous compound.

Gold is precipitated from its solution by most metallic substances; the precipitate occasioned by tin is of a purple colour; it is used by enamel painters for giving a purple colour to glass, and is called purple powder of Cassius.

Sulphuric ether added to a solution of gold combines with the oxide of that metal to form an ethereal solution of gold. Polished steel may readily be gilded by immersion in this solution.

The combinations of gold with sulphur, sulphuric acid, and phosphorus are unimportant.

Gold may be alloyed with most of the metals, those formed with silver and copper are the most important. Standard gold is an alloy of eleven parts gold and one part of copper.

The alloy of gold with mercury may be made in any proportions; the larger the quantity of mercury the softer the amalgam produced. This amalgam is used in the process called water-gilding; the amalgam being applied to the surface of silver, the mercury is driven off by heat, while the gold adheres.

PLATINUM occurs in the state of small grains in South America; in this state it is called crude platinum, and is usually mixed with lead, iron,

palladium, iridium, osmium, rhodium, and sometimes a little gold. To obtain pure platinum the ore must be dissolved in nitromuriatic acid, composed of one part nitric and three parts muriatic acid; solution of muriate of ammonia must then be added, which will occasion a precipitate of ammonio-muriate of platinum; this substance, having been heated, must be redissolved in nitromuriatic acid, and again precipitated by muriate of ammonia; the precipitate thus obtained must be submitted to a white heat: the acid and alkali will be expelled, and pure platinum will remain, which may be rendered more compact by pressure while it is very hot.

This metal has a white colour and brilliant lustre: it is very malleable and ductile, and is unalterable by exposure to air, heat, or the most concentrated simple acids. Its specific gravity is 21.5; so that it is the heaviest body in existence. Its atomic number is 96.

Platinum may be made to combine with oxygen in different proportions, but these combinations seem to be involved in some uncertainty, and they are unimportant: as is chloride of platinum.

When platinum is precipitated from its solution by muriate of ammonia, an ammonio-muriate of platinum is obtained, which being heated in a crucible under a slight pressure, affords the substance called spongy platinum. This substance has the remarkable property of becoming ignited

when a small stream of hydrogen is made to flow upon it, so that the heat of it speedily inflames the hydrogen; on this account it is applied to a vessel containing hydrogen, and having a very small aperture, regulated by a stop-cock, for the purpose of obtaining instantaneous light. A minute quantity of the spongy platinum is sufficient for the purpose, and it will serve a long time if it is covered over when not in use. Spongy platinum is also useful in the analysis of gases, as it occasions the combinations of oxygen and hydrogen at common temperatures, water being produced. For this purpose the spongy platinum is mixed with fine clay, and made into balls about the size of peas. Other forms of platinum have the property of making these gases combine; and some other metallic substances, particularly iridium, become hot and ignite when submitted to a small stream of hydrogen.

Pure platinum is of great use in chemical researches, and in some processes of the arts and manufactures, on account of its power to resist heat and acids. It has the property of welding like iron, and it may be united to iron or steel in the same way.

Platinum is capable of forming alloys with a large proportion of the other metals; but, although some of these have been much approved, they have not been extensively used on account, most probably, of the high price of platinum. An

alloy of seven parts of platinum with sixteen parts of copper and one part of zinc, is said to resemble gold. A good alloy for cutting instruments is made by combining steel with about three per cent. of platinum.

SILICIUM. It is supposed, from analogy, that the base of silicious earth is a metal; but hitherto it has not been obtained in a pure metallic state.

Oxide of silicium, or silicious earth, is one of the most abundant forms of matter. To obtain it in a state of purity, it is sufficient to reduce rock crystal to a fine powder. This earth is insoluble in water, difficult to fuse, and of a white colour. Silica melted with potash or soda, forms glass; but, when the quantity of alkali is excessive, a liquid solution of the earth is obtained, from which it is thrown down by the addition of acids, in the state of gelatinous hydrate.

Glass is of different qualities, according to the nature of its ingredients.

Flint glass was formerly made of ground flints, whence its name; it is now made in many places of 100 parts purified Lynn sand, 60 parts litharge or red lead, and 30 parts purified pearlash. This glass is exceedingly brilliant when cut, and it is the most useful kind of glass for optical uses; it is so soft as to be easily scratched, and softens at a dull red heat. The perfect fusion of this glass requires about thirty hours. A little black oxide of manganese corrects a tendency to a green

colour, in consequence of the presence of combustible matter, or oxide of iron; and sometimes small quantities of nitre and arsenic are used for similar purposes.

Plate glass is composed of 43 parts pure sand, 26.5 parts of dry subcarbonate of soda, 4 parts pure quicklime, 1.5 parts nitre, and 25 parts of broken glass. From these materials about 70 parts of good glass may be obtained. When perfectly fused it is poured upon a hot copper plate, where it is rolled out; it is then placed in the annealing oven, and is polished by grinding it with sand, emery, and the substance called colcothar.

Crown glass, which is fine window glass, is made of 200 parts by weight of fine purified sand, and 330 parts of best kelp. The mixture is submitted to heat in the fritting arch, by which sulphur is expelled from the kelp, and the substances well incorporated; at the end of four hours the mixture is taken out, and forms a greyish-white tough mass, which is cut into pieces, cooled, and piled up for use. When long kept there is frequently an efflorescence of soda upon the surfaces of these pieces, by which they are supposed to be rendered more valuable.

Broad glass is an inferior kind of window glass, which is made of soapmaker's waste kelp, and sand. The proportions vary according to the quality of the ingredients.

Bottle glass is made of soapmaker's waste kelp, and river sand.

None of the acids are capable of acting upon silica with energy, excepting the hydrofluoric acid, which dissolves it, and forms with it silicated fluoric acid gas: this gas is sour, acrid, and colourless; combustible bodies cannot burn in it, and it occasions white fumes while diffusing itself in a damp atmosphere.

ALUMIUM has never been obtained separately in a pure state, but analogy and experiment combine to produce a conviction of its metallic nature.

Oxide of alumium, or alumina, may be procured in a pure state, by washing and igniting the precipitate which is thrown down by adding carbonate of ammonia to solution of alum; it is white and tasteless; it forms a cohesive mass when mixed with water, and has such a strong attraction for that fluid, that a red heat cannot expel it entirely. This earth combines with potash and soda, and enters into several other compounds; one of the most important of which is alum, which is a triple sulphate of alumina and potash.

Alum has an astringent and somewhat sweetish taste, it crystallizes in regular octahedra. It is capable of being dissolved by sixteen parts water at 60° , and by three-fourths of its weight at 212° . When this saline substance is exposed to air, it effloresces on its surface, and it melts in its own

water of crystallization on being submitted to a gentle heat. It has the property of changing vegetable blues to red. Its specific gravity is nearly two.

Alum is prepared in the large way near Paisley, at Whitby, and other places, by burning a sulphurous clay slate, called alum shale. The stratum from which it is obtained near Whitby is thus described. It is about twenty-nine miles in width, and it is covered by strata of alluvial soil, sandstone, ironstone, shell, and clay. Alum schist is generally found disposed in horizontal lamina. The upper part of the rock is the most abundant in sulphur; so that a cubic yard taken from the top of the stratum is five times more valuable than the same bulk one hundred feet below.

Alum is used in a great variety of processes in the arts. It is of great use in dyeing, for cleansing and opening the pores of the substances to be dyed, and rendering it fit for receiving the colouring particles, which it helps to fix. It is used in tanning, in the preparation of lakes and other colouring substances. It is used in calico printing. In small quantity added to turbid water, it renders it clear; and renders bodies saturated with it less liable to take fire.

In Homberg's pyrophorus alum is a principal ingredient. To prepare it, equal parts of brown sugar and powdered alum should be mingled

together, and melted in an iron ladle, and stirred until dry; the dry mass should be pulverized, and put into a common phial, previously coated with clay, and placed in a crucible containing sand. When it attains a red heat, a blue flame will issue from the neck of the phial, which should be allowed to burn about five minutes, the phial should then be removed from the fire, and effectually closed to prevent the admission of air. The substance thus pulverized, when cold, will take fire on being thrown out of the bottle into the atmosphere.

Alumina is an essential ingredient in earthenware, the varieties of which are numerous; and in the manufacture of the finer kinds, the processes are highly elaborate and refined, and intimately connected with chemistry. Various modified methods are adopted for making white earthenware, of which the following is one: Dorsetshire pipe-clay is intimately mixed with water, allowing the coarse particles to subside, and the mixture is made to pass through hair sieves of different degrees of fineness. Another liquid mixture of calcined and pulverized flints is prepared in a similar way, so that its density may be the same as that of the other; they are then mixed together, and the water is evaporated by heat, and the mass is worked up into a fit state for being turned upon the wheel, or moulded into the required shapes. The vessels prepared in this way are dried, and

then packed in strong vessels of baked clay, called seggars, which are piled upon one another until the dome of the furnace is full. The fire is then gradually raised to the proper temperature, which is effected in about twenty-eight hours; common salt is then thrown in through holes in the upper part of the furnace; it is converted into a thick vapour, which, entering the seggars through openings left on purpose, is applied to the surface of the earthenware, and forms a vitreous covering or glaze upon its surface.

The yellow or queen's ware is made of the same materials in different proportions, and glazed differently. In this ware there is a larger proportion of clay; sometimes twenty, and sometimes twenty-four measures of clay are mixed with four measures of flint, by weight; about three hundred weight of clay to one hundred weight of flint. The proportions, however, are very much varied, and depends on the nature of the clay. For the glaze of this ware, 112 pounds of white lead, 24 pounds of ground flint, and six pounds of flint glass, are mixed with water to the consistence of cream. The ware, after having been baked, is dipped into this liquid, of which it imbibes a portion, and which occasions a thin vitreous coat, when the ware is again submitted to the fire.

Clay obtained from decomposing felspar is extensively used in the Staffordshire and other potteries. The patterns applied to earthenware are

first printed upon paper, and immediately transferred to the surfaces of the earthenware before it is glazed, heat being applied to fix the patterns. Blue is the predominant colour, because of the convenience and facility which cobalt, as a colouring substance, affords.

The finer kinds of earthenware, called porcelain and china, are required to be of a beautiful white colour, to be tough and translucent, and to be capable of bearing a high degree of heat without fusing.

The art of painting upon china is carried to great perfection, especially when we consider that the preparations of the metallic oxides used in this process are of different colours when applied, to those which are intended to be produced when the process is finished, as they change when exposed to the fire.

The manufacture of crucibles for various processes in the arts, is an important branch of pottery. As all mixtures of silicious and aluminous earths are liable to soften by the application of great heat, crucibles made of pure clay are the best adapted to sustain high degrees of temperature; burned clay, coarsely powdered, being substituted for sand in making them. By coating the inside of a common hessian crucible with pure clay, it is rendered applicable to some purposes for which it would not otherwise answer.

ZIRCONIUM is the supposed metallic base of

the earth zirconia, which is accounted an oxide of zirconium. It is obtained from the zircon of Ceylon, and also from the hyacinth; its specific gravity is 4.3; it is white and insipid; carbonated alkalies dissolve it, but not the pure alkalies. To obtain pure zirconia, the stone must be calcined, dipped in water, and pulverized; the powder must be mixed with nine times its weight of pure potash, and the mixture gradually projected into a silver crucible heated to redness, in which it must be kept for two hours in a state of fusion. When cold the mass must be pulverized and boiled in distilled water. What remains must be dissolved in muriatic acid, filtered, and evaporated to dryness. The dry mass being dissolved in distilled water, must be precipitated by the addition of carbonate of soda: carbonate of zirconia will be produced, which being decomposed by the application of heat, pure zirconia remains.

GLUCINUM. The supposed metallic base of the earth glucina, which is accounted an oxide of the metal. Glucinum was discovered by Vauquelin in the beryl, and it has been found in the emerald and the euclase; and may be obtained pure from these minerals. It is soft, white, light, and insipid, insoluble by water, and infusible by heat. Potash, soda, and carbonate of ammonia, are capable of dissolving it. Its salts have a sweet and rather astringent taste.

YTTRIUM. It is believed that the earth yttria

is the oxide of a metal which is called yttrium. This earth was discovered by Professor Gadolin, in a mineral, which is now called Gadolinite, from Ytterby, in Sweden.

This earth when pure is white, inodorous, and insipid; insoluble in water and fixed alkalies. Its specific gravity is 48.42.

THORINUM is the supposed metallic base of the earth thorina which was discovered by Berzelius, in examining some varieties of gadolinite.

This earth is found in very minute quantities only, and the process for obtaining it in a state of purity is tedious and difficult.

Thorina resembles zirconia, but differs from it, and the other earths, in some of its properties; from alumina and glucina, by its insolubility in solution of potash; from yttria, by its astringent taste without sweetness; from zirconia, by being soluble in acids after having been heated to redness; in not being precipitated by sulphate of potash; in being precipitated by oxalate of ammonia; and in the crystallization of its sulphate, the combination of zirconia and sulphuric acid not being capable of crystallizing.

THE END.

